Signals Intelligence and Analysis

with
Gary Smith

T46-E



VISION Hi-Tech Training & Expo

WTI WORLDPAC Training Institute

DiagNation

SIGINT: Are Diagnostics a Challenge?

- Most calls on our hotline involve good techs stuck on some issue that has not been resolved by conventional diagnostics and DTC charts.
- Some of this is due to “inefficiencies” or incorrect test methodology called out in OEM service info.
- Some of this is due to the fact that we all were trained into the diagnostics business differently, **and at VERY different levels of understanding**, mechanically, electrically and ELECTRONICALLY.
- Because of this, in an overwhelming number of cases we solve, **it was a very BASIC fault, *masked heavily in high technology***.

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What is Measurement and Signatures Analysis?

- Measurement, we are (relatively) familiar with. We perform multiple measurements every day, some mechanical, some electrical and some BOTH.
- Signatures refers to the electrical characteristics and behavior of a given circuit under (or out of) control.
- Based on physical Laws and engineering science (Math, Chemistry and Physics… AKA Math…) certain signatures are expected throughout the circuit, depending upon it's components and configuration.
- This class is about learning the base operating theory of "Electronic" components and the **SIGNATURES they produce**.

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Scopes, Waveforms and Answers

- In many of these cases, the tech was missing the fault on his scope screen due to a lack of understanding the FUNDAMENTALS of electrical behavior.
- We understand how to connect, acquire, tune and filter our signals, ***but what ARE the signals, where did they come from, HOW were they derived***?
- There are 4 or 5 BASIC, (Tick-Tock) electronics components and configurations that govern the ***ELECTRICAL BEHAVIOR*** of most ALL sensor inputs, module processing and output power controls.
- You will see that once these are known and studied, the answer to most problems has been on the screen the whole time, we just ***MISSED*** the fault for lack of fundamentals knowledge and practice.
- ***We often just "Out-Tech" ourselves.***

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Hence the Term…

***MIS*-Diagnosis**

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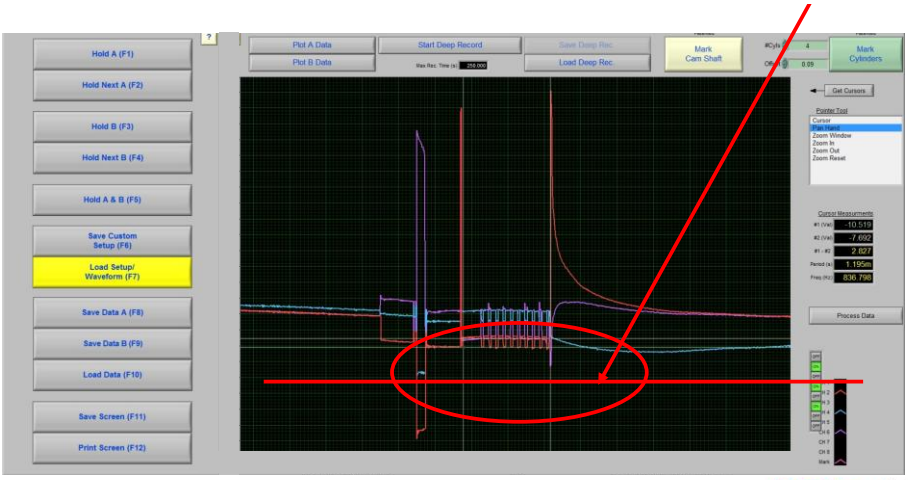
Good, or Bad? You Make the Call!



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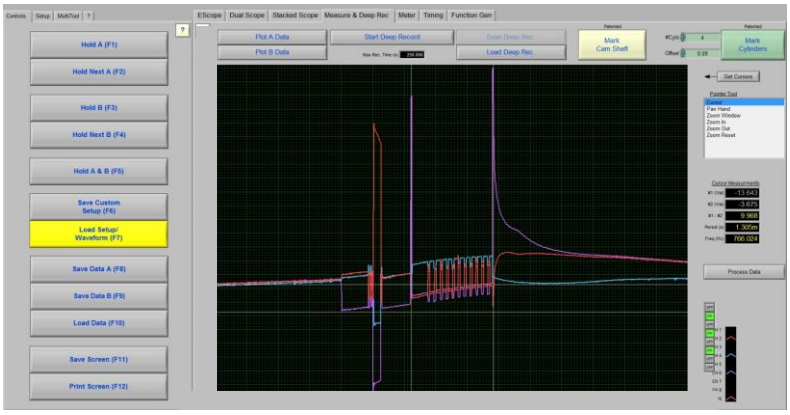
Cylinder 7 Injector:
Red Trace
Inductive Kick: 70v
Pulse Width: 1.119ms
On Lift: 2.8v
Closing Hump: No
C.H. Occurs: No

Good, or Bad? You Make the Call!



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DiagNation

Cylinder 12 Injector:
Purple Trace
Inductive Kick: 75v
Pulse Width: 1.315ms
On Lift: 9.9v
Closing Hump: Yes
C.H. Occurs: 334us

Signal Processing: What Makes it Tick?

- The engineering in today's vehicles, the sheer scope of MATH and physical law involved, as well as the algorithms and coding to make an ECM, BCM or ADAS Autonomous Radar Cruise Module work are FAR beyond the scope of our knowledge. (Most of us, anyway…)
- Engineering teams of thousands are involved in the design, production and launch of any given model. Even they don't know all of the pieces to the puzzle, so to speak.
- **None of that technology really matters to us**. The answers to the problems we struggle with are often rooted in technology that was made available to us 100 years ago.
- We will go back in time and carefully look at this technology.

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We will go back in time and carefully look at this technology.

A Focused View of *ELECTRONIC* Fundamentals

- Electronic fundamentals put to use with incredible inventions back in the period between **1820 and 1920** forms the ***basis*** for EVERY electronic signal we could possibly want to diagnose today in the 2020s.
- The PHYSICAL fundamentals, (The Laws) and the basic building block components' function ***IN*** electronic circuits have not changed either.
- Signal processing, modulation, transportation, decoding and output behavior ***HAVE NOT CHANGED electrically***, only the complexity, size and the addition of computer coding have changed.
- ***Study THE Fundamentals and you have CRACKED the CODE.***

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The Most Insane of Brains….

A History of the Titans of Electricity and Invention

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The Titans of Electrical Discovery and Laws

- **Georg Ohm** (Ohm's Law, V=IxR)
- **Gustav Kirchhoff** (Kirchhoff's Laws, KVL, KCL)
- **Michael Faraday** (Faraday's Law of Induction, Capacitance - Farad)
- **Andre Ampere** (Ampere's Law, quantified current flow)
- **Alessandro Giuseppe Antonio Anastasio Volta** (Invented 1st battery, 1st source of continuous current, quantified the Volt)
- **James Watt:** Concept of Horsepower, Work (P in Watts = I x E)
- **Heinrich Hertz:** Defined and proved frequency characteristics of electrical waves and explained them mathematically. (f=Hz)

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The contributions of these early pioneers of electricity to the industry we work in today cannot be understated. These guys were mechanics, technicians and problem solvers of the highest order, our ability to understand electricity, control it and use voltmeter, scopes, scanners and other electronic diagnostic tools would never be possible without these guys. The discoveries, inventions and Electrical Laws proven by the group listed above, and more… have literally changed the world. Their Laws still stand today, applied to all manner of engineering and diagnostics.

One never ending "Self-Study" mission we should all be on is to read this history and study, learn and apply what the "Forefathers of Electricity" have given us.
Herein lies the solution to 90% of our industry's pain in modern day diagnostics.

Physical Laws Not Defied Since Discovery

- It is important to note for diagnostic technicians that the Electrical Laws that governed the early pioneers are ***STILL*** used in all engineering and deployment applications in 2024.
- In **200 years**, the physics of what these genius brains figured out, proved and documented have not changed nor been defied, ***TO THIS DAY***.
- This is SIGNIFICANT in our diagnostics of high-tech systems today.
- As a matter of fact, these are the keys to truly understanding what we do.
- There are certain things we can depend on within these basics that will help us with the most advanced of diagnostic scenarios.

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An Advanced example

DC H-Bridge Automotive Motor and Solenoid Driver Chip with
Integrated MOSFET Drivers

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Throttle Motors and other Inductive Loads Driven by Chipsets

- How many times have we replaced that ETM more than once to find it still intermittently defaults?
- In an OVERWHELMING number of cases, voltage supply, pin tension, bad grounds or corrosion in connectors is the cause of this.
- Many times, an intense intermittent ghost diagnostic can be avoided if we focus on what the logic doesn't like.
- ***Sometimes we have to research and understand things the OEM will not publish.***
- The answer, therefore, can ***almost ALWAYS*** be isolated by studying the data and ***electrical BEHAVIOR*** on input or output circuits, which can be analyzed with a scope waveform.

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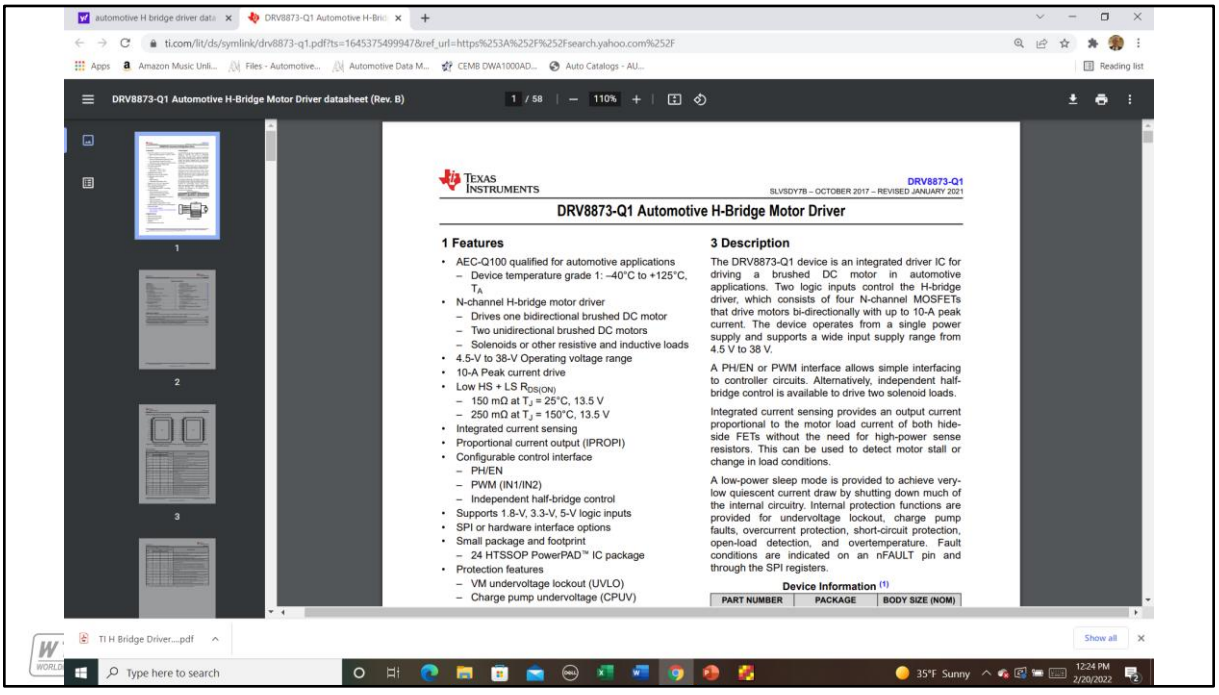


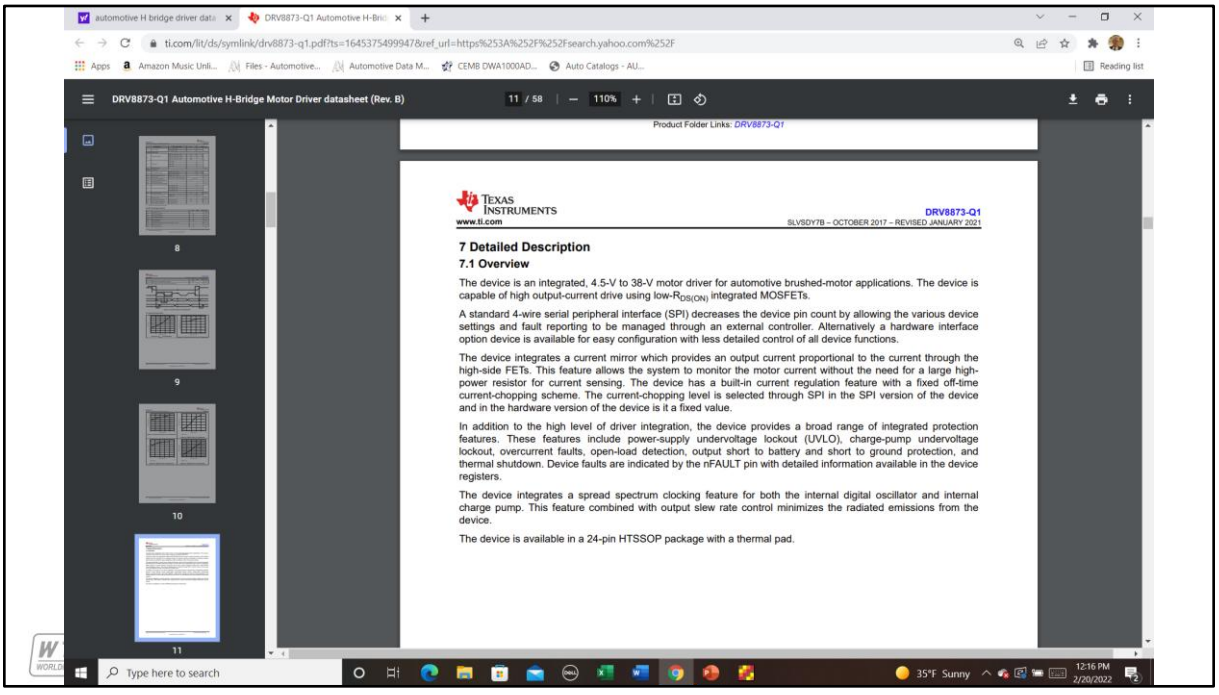
A Data Sheet for any modulized control chip can provide diagnostic clues the OEM doesn't provide in schematics or service information. Specifically, voltage, current and other chip specifications can be extremely helpful, for example, reading the protection features for the chip clearly explains trigger parameters and logic responses to these problems. Many Integrated Automotive control chips (Integrated meaning drivers built into the chip itself) that drive inductive loads will have robust chip protection schemes for situations where the driver can be destroyed by the "loss of inductive control" within the circuit.

As a rule of thumb, most ALL of these control chips' data sheets will describe in detail what the chip will do when a fault occurs.

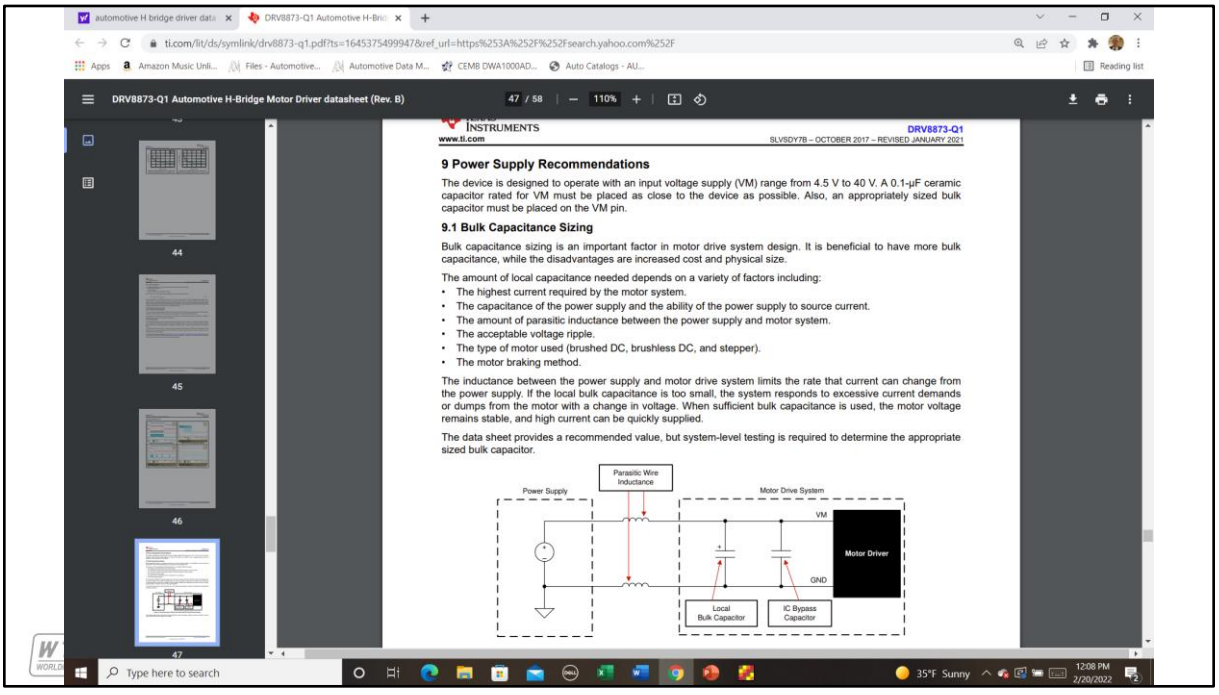
Almost every one calls out 4 common things that cause chip resets:

(1) Undervoltage Condition: (Causes UVLO Lock out, this is where the throttle no longer works, for example)
(2) Undercurrent Condition: (Same, default lockout)
(3) Overvoltage Condition: (Same, default lockout)
(4) Overcurrent Condition: (Same, default lockout)

This behavior can often clearly explain the driver's description of the problem. (Starts right up when towed in!)

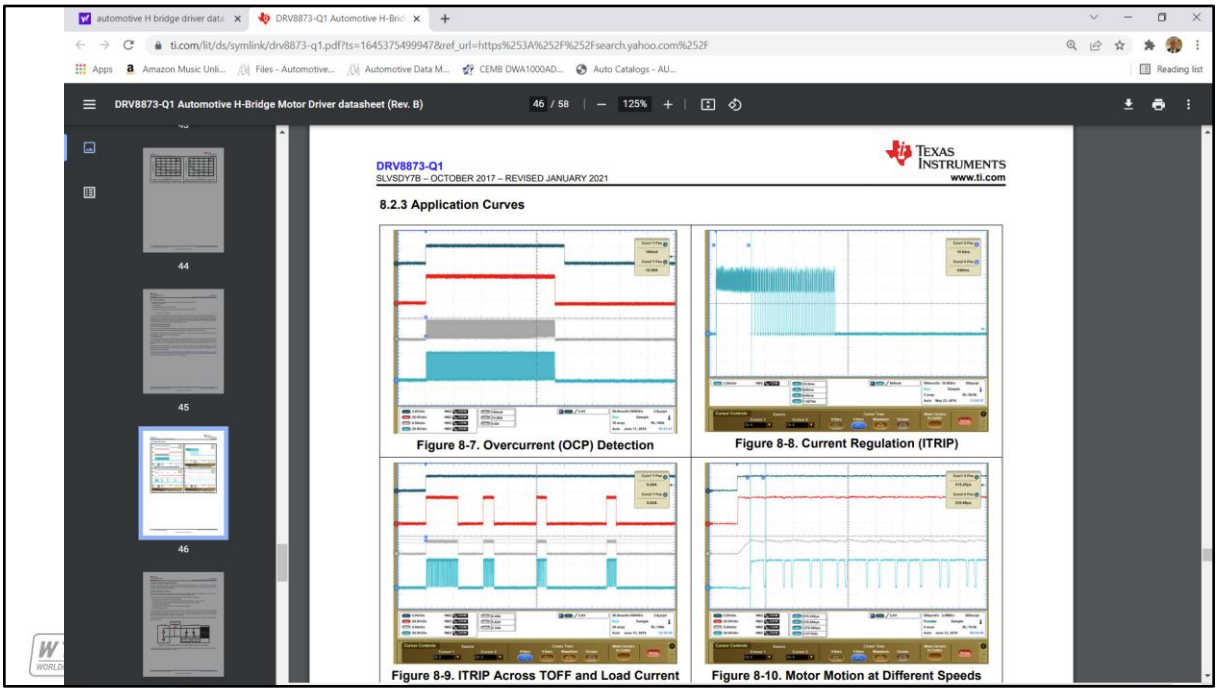


The detailed description here is a great example of those protection statements and provide valuable information to understanding “Ghost” complaints.



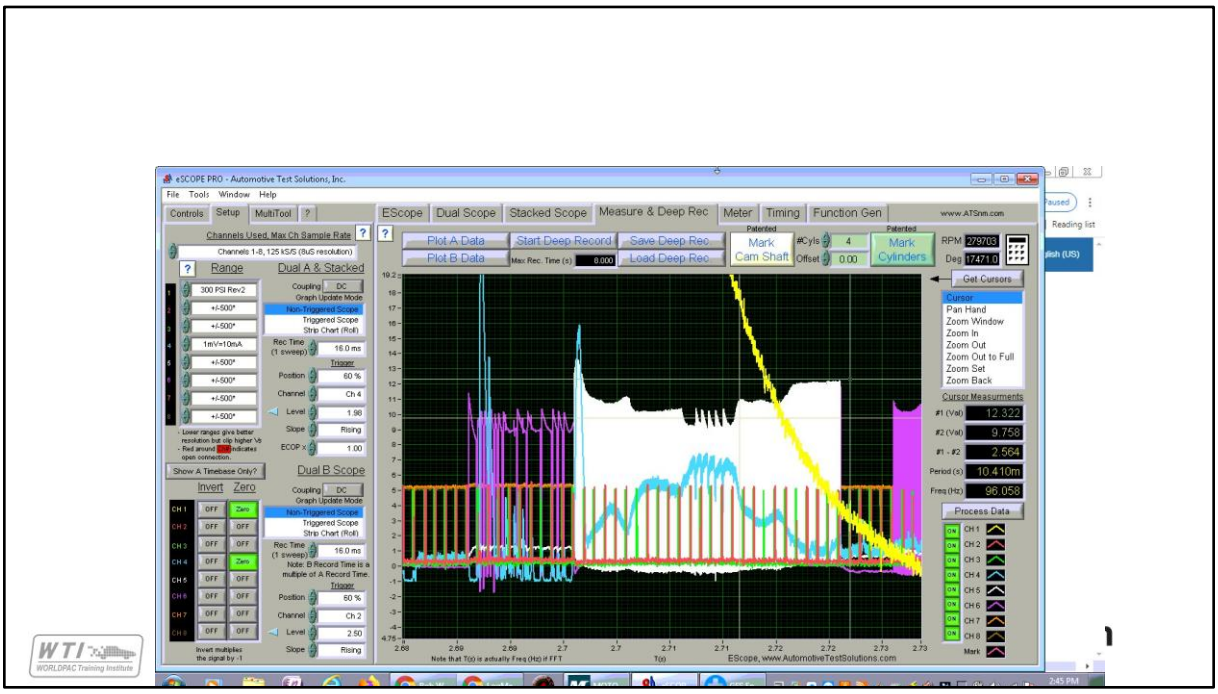
Here we can see the importance of understanding the ***SIGNATURES*** of certain components, such as the capacitors seen in this TI Chipset Data Sheet.

If we look at our real-world case study, there is gold in the understanding of this particular ***SIGNATURE***. In many cases, being able to interpret the physical signatures of electrical behavior allows the technician to (A) “See” the problem where it would otherwise be missed, and (B) interpret whether the fault is external to the wiring, or internal logic-style electrical behavior.
The example here would be identifying a capacitive discharge signature of the output waveform.

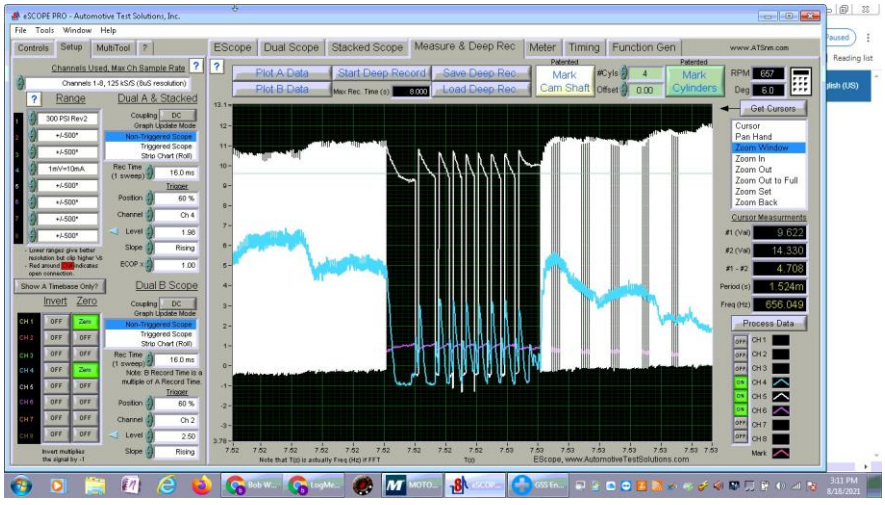


A data sheet will also (typically) provide expected performance and scope waveforms to show key points of performance at these fault trigger points and show typical operating characteristics.

In many cases, research on this level can provide understanding of the circuit theory and function, as well as the fault conditions and module behaviors.



Here is a shot of a vehicle having a major control problem with voltage (In WHITE) and the reaction of the control chip when this motor was shorting. The (BLUE) trace is set up to view current LEAKAGE, (Not level), which can be detected in the white voltage overlay. As the motor heats up and shorts, we can see the reaction in the voltage, as well as the chip trying to cycle the fault. The next page shows what the chip does during this reset. Remember, that current should be right around ZERO during this test, as the current clamp is around all the power wires for the motor. According to KCL, the algebraic sum of all currents into and out of a node should equal ZERO. When measuring this way, the BLUE trace you see rise up on the white is the motor showing its short (leakage) which quickly throws this BMW into a TIZZY.



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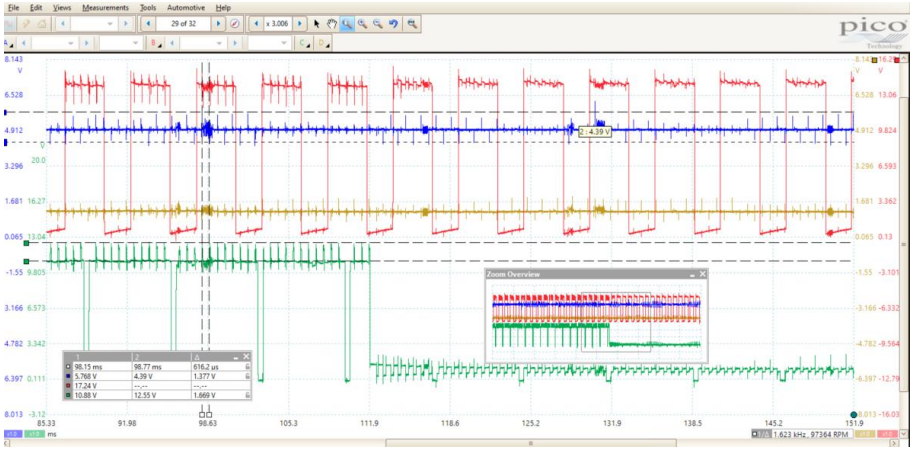
Here we can see the intermittent nature of the fault. At this point in the capture, we can see the current activity of the motor follow the voltage clearly.

Keep This Slide In Mind for Later…



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Here is another INTERESTING case related to drivers we will look at later in the course.

The Titans of Invention

- **Thomas Edison:** (Electric Car 1913, Lighting Systems)
- **Nikola Tesla:** (AC power, Lasers, Feedback Loop, Autonomous Controls)
- **Edward Weston:** (Measurement, Voltmeter, Ammeter, Ohmmeter)
- **John Fleming:** (The Fleming Valve Diode, Vacuum Tube)
- **Lee De Forest:** (First Triode allowing amplification, 1st amplifier)
- **Arthur Atwater Kent:** (Titan of Radio, Invented the Ignition System)
- **William Shockley, John Bardeen and Walter Brattain:** Invented the semi-conductor transistor in 1947 at Bell Labs/AT&T.

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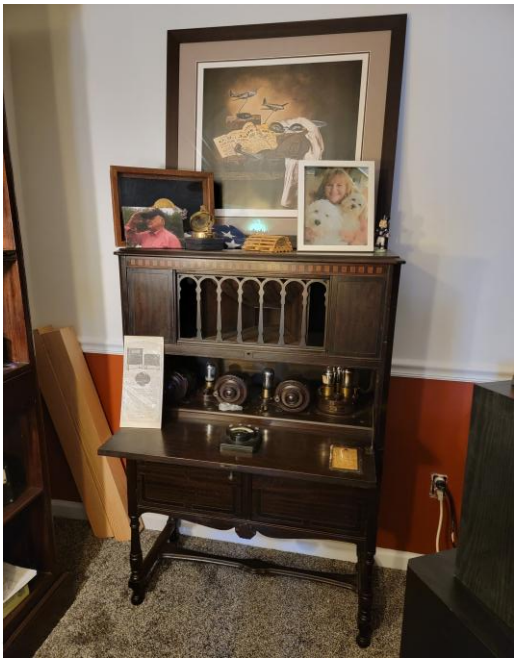



Atwater Kent was a huge early electrical titan especially for Automotive applications. He invented breaker points, the ignition coil, and was one of the first outside parts and systems suppliers to the Automotive Industry. His biggest contribution, however, came in the form of automotive charging, rectification and ignition system development. Atwater Kent introduced the new art of signal processing to the engine bays and body systems of automobiles. History never speaks of Kent in relation to automotive early development, yet there he was, amongst the Titans.

The picture is of an extremely rare Atwater-Kent model 1100 Pooley, the first radio ever built into furniture. The radio inside is a 1923 Model 10B Breadboard, one of the rarest of early production radios in existence. This piece was out of circulation for 65 years, and is a full-on museum-quality piece of history.

Modulation – Creation and Manipulation?

- Morse code was the ***MODULATED*** signal which conferred data from one point to another.
- The signal was CREATED by making and breaking an electrical "Key" to create electrical blips of DITs (Dots) and DAHs (Dashes) by varying the TIME the operator kept the key contact closed. (Dwell or PW)
- The Dits and Dahs were then translated (by constructing and deconstructing letters) and messages were transmitted and decoded in this fashion.
- If we look at this on a scope, what would it look like?



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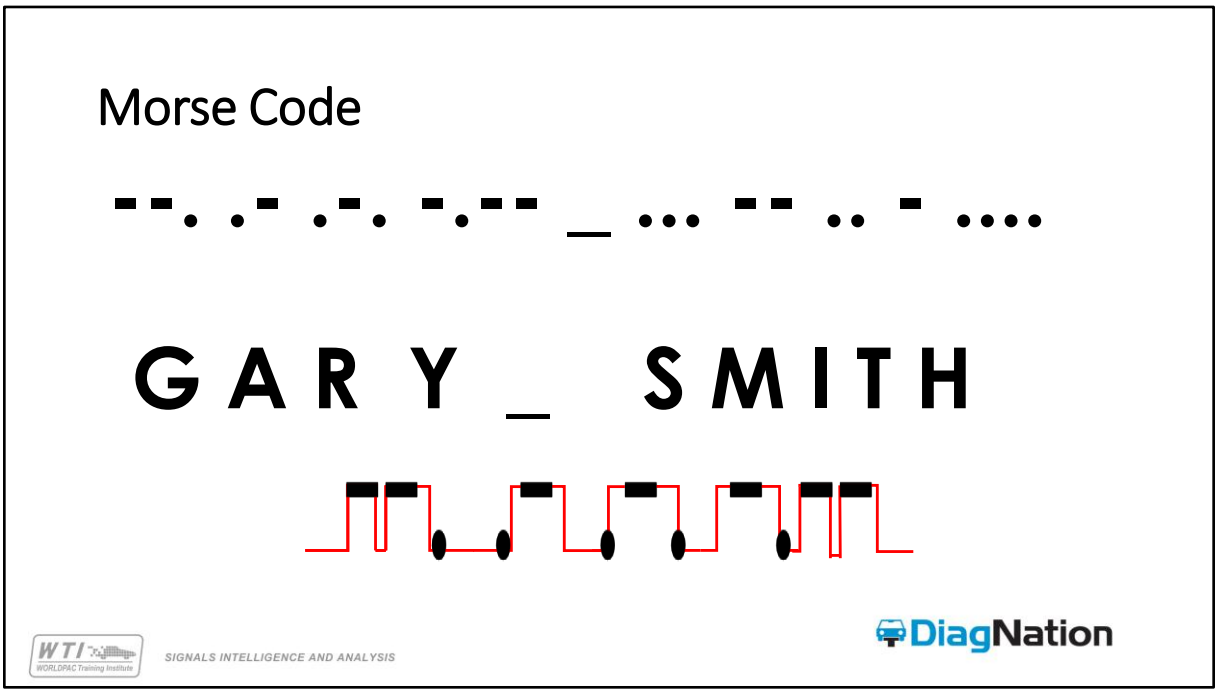
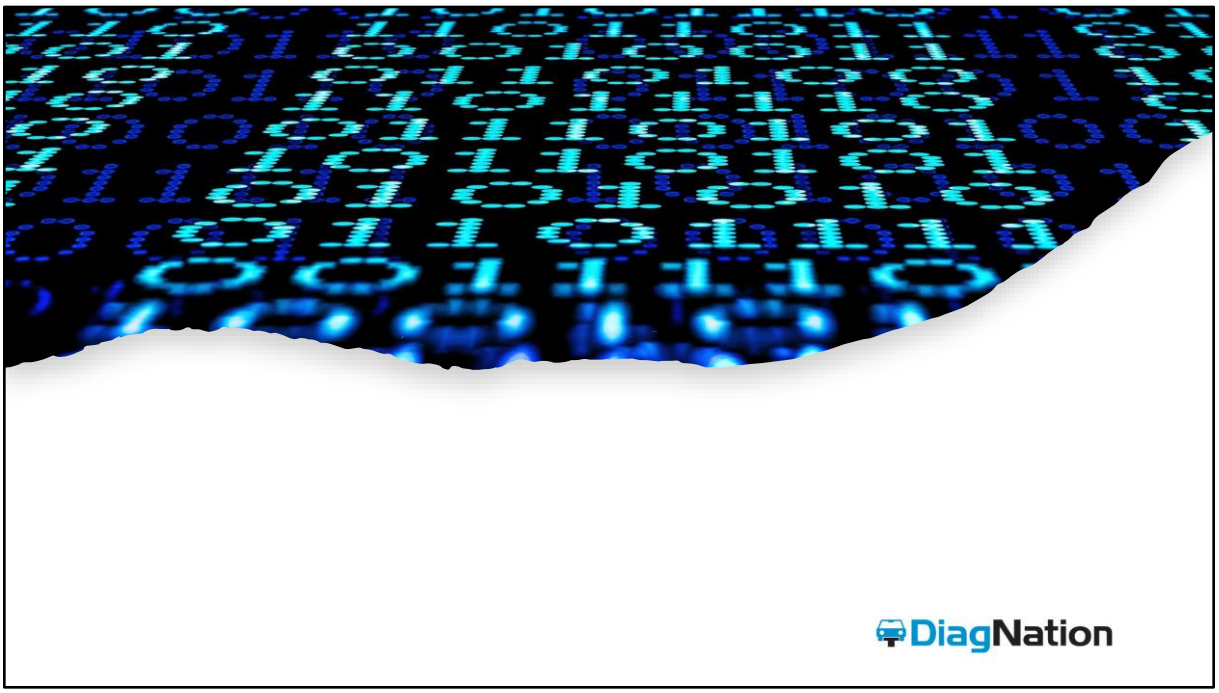
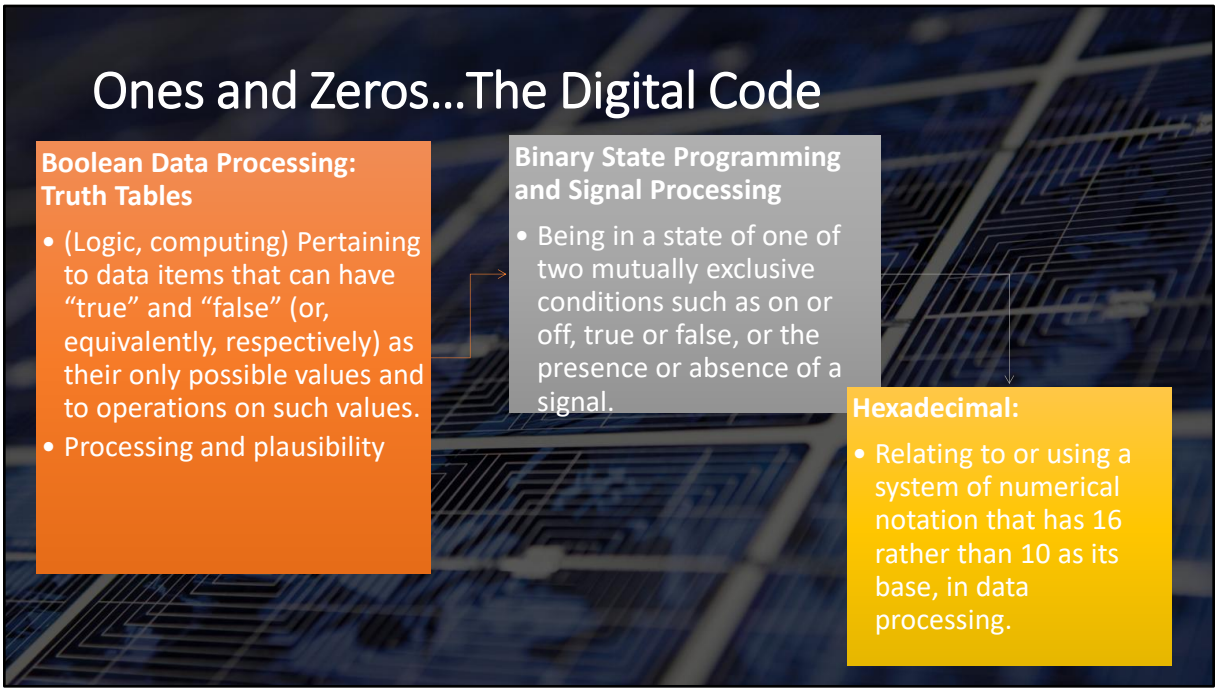


Morse code is actually the genesis and basis of most ALL modern signal and data processing. The principles of voltage and time modulated signals forms the basis of everything we measure and diagnose in modern platforms.



This class doesn't key in on computer language, coding, etc. Suffice it to say, this is the area we will LEAST likely touch or get involved in during diagnosis, yet it is critical to learn the basics of ADC/DAC processing for our diagnostic knowledge. This is true because Boolean and Binary languages are the coding behind the logic, behind the computer modules, wiring and electromechanical controls in the vehicle.

We should at least learn the basics of theory here, as the ones and zeros are always processed as a HI or LO signal, a zero or a one… in square-wave format.



The basis of all computer functional operation. Inputs and outputs alike are broken down to this inside the box's IC Chips.

PROGRAMMED output commands ALWAYS reflect what the processor analyzed based on it's inputs AND programming tables.

Boolean (1840s to 1864) truth tables are consulted for MCU output decisions **AND for plausibility checks.**

We measure our voltages, currents and pressures to then analyze the signatures and electrical behavior.

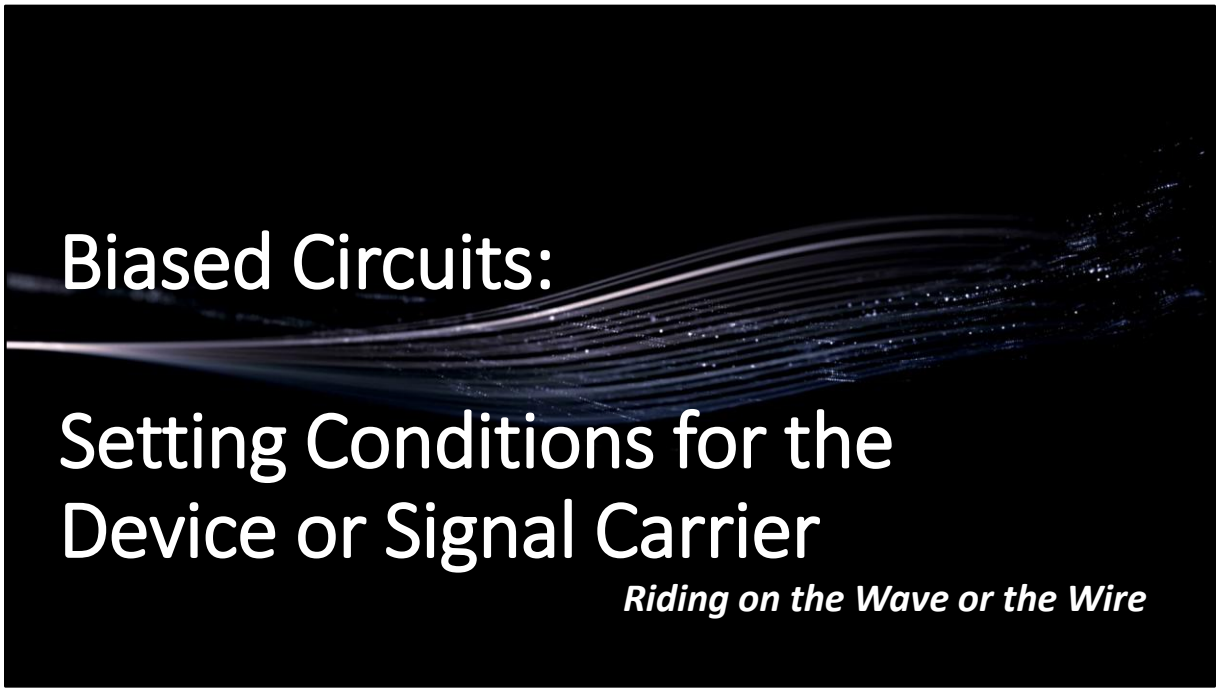


Signal transport is where automotive techs spend most of our time, and this is why the study of ***fundamentals and SIGNATURE analysis*** is a skill we do NOT want to bypass in our learning curves. This is the basis of what we do in diagnostics.

Signal transport in our case is normally wiring, or balanced twisted pair for CAN and networks, however, RF is becoming an increasingly popular way for OEMs to convey info. RF signals for remote access, keyless entry, push button start, park assist, radar cruise and many other automotive systems have RF transport in the control path.

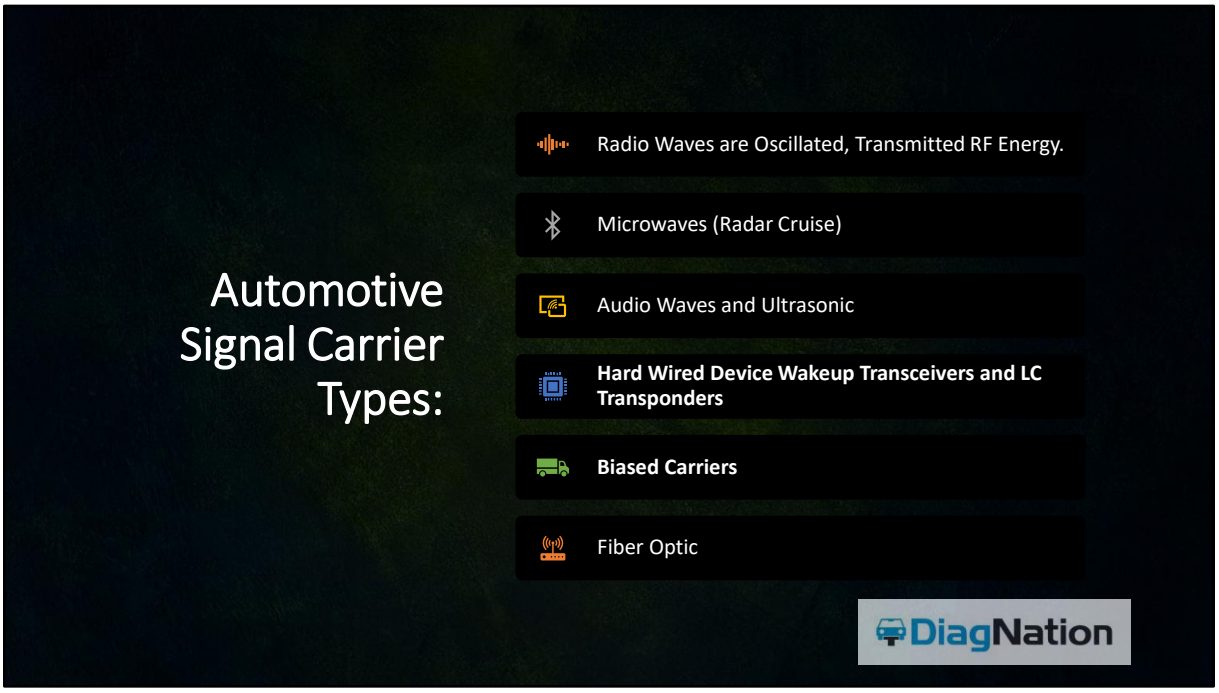
Technicians working on newer platform vehicles will need to learn how to ***capture, read and analyze RF***. Learning RF requires study of the fundamentals in this class, which if pursued beyond this class will provide a lifetime of learning.

Understanding the modulation of signals, the transport of signals and the PROCESSING of the signals can be a lifelong study.



The modulated signal (In OR out) must ride on something… a wire, an RF wave, Ultrasonic or Radar wave, light waves, (laser, IR, fiber optic) or a network twisted pair… an antenna… some medium ***MUST carry the signal***, for it to be processed. Our job as techs, is to break down the circuit or system and find out whether it is the signal itself that is faulty (from maybe a bad sensor) or whether the signal carrier is at fault. (The wiring, balanced antenna, or transmitter or receiver)

The signal carrier with the modulated signal will be critical for the processor to perform signal processing and logic decisions properly.



Radio Waves are Oscillated, Transmitted RF Energy.
Microwaves (Radar Cruise)
Ultrasonic (Park Assist Systems)
Hard Wired RF– Device Wakeup Transceivers and LC Transponders
Biased Carriers (Oxygen Sensors, Wheel Speed Sensors, CAN and Networks)
Fiber Optic (MOST, Media Oriented Systems Transport)
Antennas

RF: Radio Frequency Waves

- Oscillator generated (resonating), transmitted and propagates through the air.
- Can be created, duplicated and manipulated, ie: SSB/AM/CW/PSK/ASK/FSK
- Can be injected with modulated signals for transport, radio, TV, Data
- The wavelength (m) = 300/(f)mHz
- 300/wavelength in (m) = Frequency in mHz
- The frequency and band are governed by FCC
- RFA Remotes in the ISM (Instrument, Medical and Scientific) band, at 315, 433 or 868mHz
- Bluetooth, Wi-Fi, NFC and other modern connections are low power radio signals

DiagNation

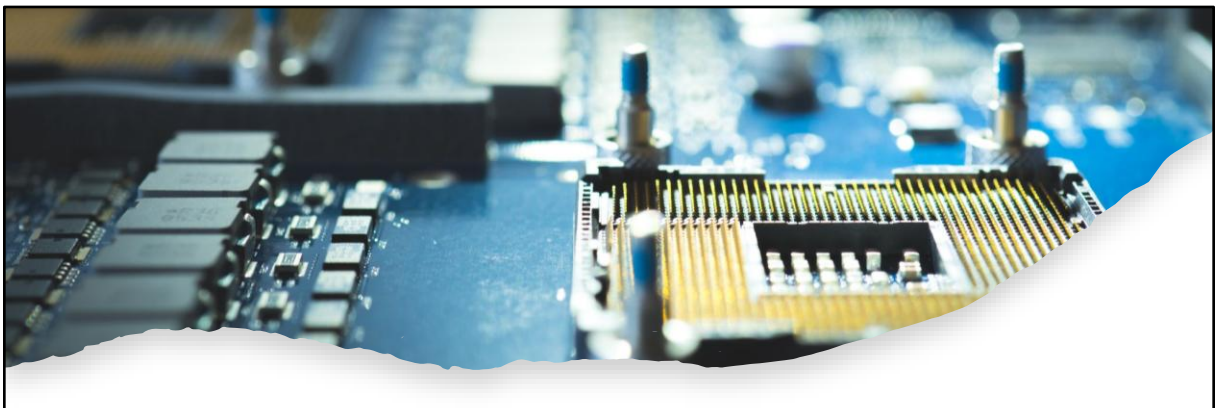
The carrier wave is typically modulated with signals or data for transport, usually voice, digital, radio or TV, Data
The wavelength (meters)= 300/ (f). The HIGHER the frequency is, the SHORTER the wavelength is.

Bluetooth, Wi-Fi, NFC and other modern connections are all radio signals. To find the antenna length to cut for an automotive remote for example: Full-Wave = 936/(f), Half-Wave = 468/(f), 1/4-Wave = 234/(f), 1/8-Wave = 117/(f) An RFA Remote transmitting at 433MHz will require a full wave antenna of 2.12 inches
A 1/8 wave antenna for that remote would be 0.26 inches… A full wave antenna length for 106.5 FM is 8.78ft. A ¼ wave for 106.5 is 4.39ft
A 1/8 wave for 106.5 FM is 1.09ft. The study of antennas, baluns, resonance and antenna types is its own lifelong study.
Google the term Smith Charts to see how deep this subject goes… wave resonance and power vs inductance and resistance, antenna wave propagation, atmospheric influence, sun cycle influence… A lifelong study indeed.

Analog Signals on Wire

- These are the signals we primarily need to measure, either on the input side, or the output side of the computer.
- [illegible] sensor and processor.
- On the output side, we will read digitally driven analog voltage and current (Mixed Power Signals)
- Even in CAN and FlexRay communications diagnostics, we are evaluating analog voltage and current performance in relation to packet transmission on the balanced antenna (Terminated) Twisted Pair

DiagNation



The Processor

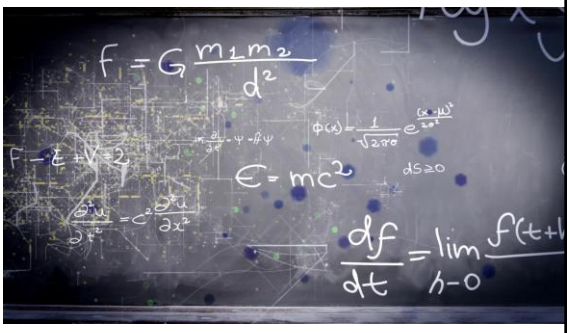
Signal IN, Signal Decoding, Signal OUT

Yin-Yout

DiagNation

Controlling Electricity:
The TICK-TOCK in the Box *Basics*

- Resistors, Potentiometers Variable Resistors
- Capacitors and Variable Capacitors
- Inductors and Variable Inductors (Rheostat)
- Diodes and Rectifiers



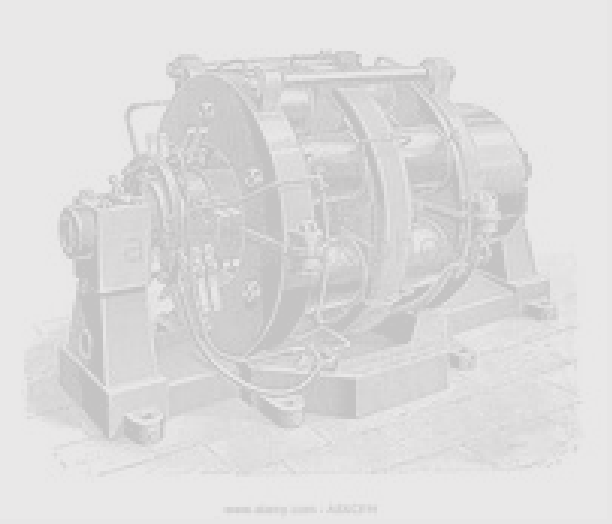
DiagNation

Sources of Electricity:

- **Generation of AC or DC Current**
- Dynamo
- Generator
- Alternator

- **Stored Energy Direct Current:**
- Chemical Wet Cell Battery
- Chemical Dry Cell Battery
- Capacitor

- **Static Electricity**



DiagNation

Sources of Electricity:
Generation of AC or DC Current
Dynamo,
Generator (Wind, water or engine providing the work)
Alternator
Electro-Chemical (Battery, Solar, Heat/Reaction)

Stored Energy Direct Current:
Chemical Wet Cell Battery
Chemical Dry Cell Battery
Capacitor

Static Electricity

Types of Electrical Current: Direct Current

- Direct current is just that, direct. When applied, direct current remains steady above or below the ground line.
- Direct current is linear until manipulated. (Capacitors, inductors and resistors)
- Direct current does not oscillate like AC current does.
- Electrons will ***ALWAYS*** flow from ground state to positive potential when excited (Switched).
- Direct current always flows in ***ONE direction*** in a circuit.
- DC voltage and current measurements are made to Reference Ground.

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DiagNation

Types of Electrical Current: Direct Current

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Direct current when applied to the circuit does not oscillate like AC current does.

Electrons will ***ALWAYS*** flow from ground state to positive potential when excited (Switched).

Direct current always flows in ONE direction in a circuit.

DC voltage and current measurements are made to Reference Ground.

Types of Electrical Current: Alternating Current

- Generated alternating current **oscillates** above and below the ground reference of 0 Volts.
- The total AC voltage equals the voltage above the ground line added to the voltage below the ground line.
- Unlike DC current which is linear until manipulated, AC current constantly oscillates at a frequency set by the transmission system, in the U.S. this is 60 Hz, or 60 Cycles per Second.
- The Positive and Negative poles alternate or switch back and forth and the current flow changes direction periodically.
- Measurements of AC voltages and currents are made “With Respect to neutral, or zero volts”.

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DiagNation

Types of Electrical Current: Alternating Current
Generated alternating current alternates, or oscillates above and below the ground reference of 0 Volts.
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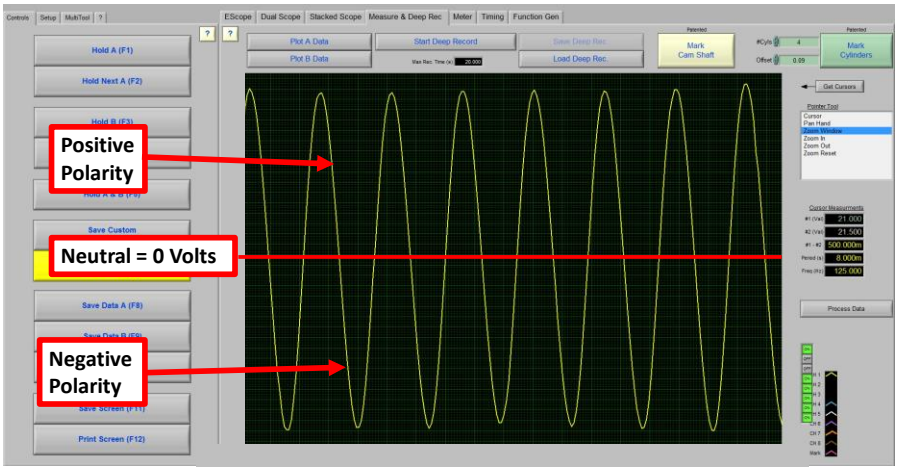
Measurements of AC voltages and currents are made “With Respect to Ground”.

AC Voltage's Polarity Changes Each Cycle



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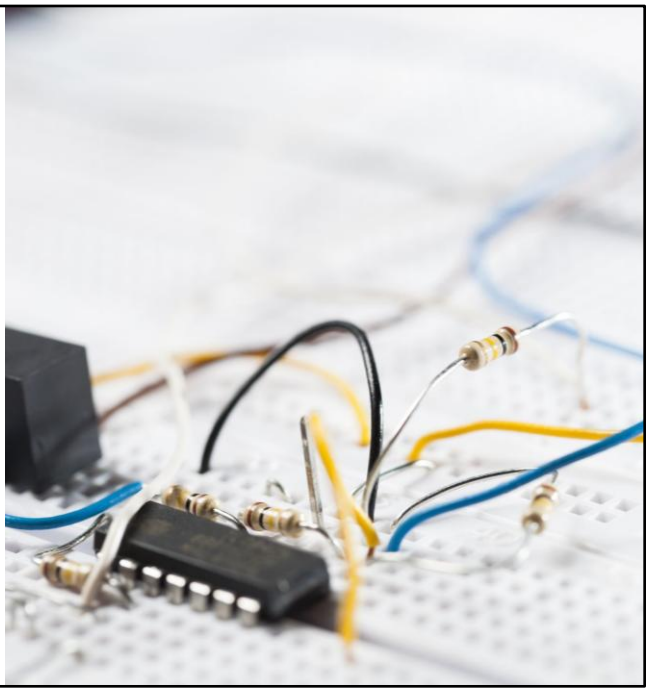
DiagNation

The **polarity** of AC voltage and current flip-flop above and below the "Neutral" line at zero volts. This kind of current flow induces fluctuations of the magnetic field, which can be manipulated and used by using inductors (chokes), capacitors and resistors. Understanding AC current flow goes beyond the concept of simple resistance and the effects on voltage and current, as in a DC circuit. To understand the BEHAVIOR of AC, we need to study the principles of Inductance, Impedance and Reactance. These electrical principles are heavily used in automotive circuits. For example: Biased sensor circuits, Oxygen sensors, wheel speed sensors, CAN networks, alternators and many other circuits. Using Inductance (Measured in Henrys), Capacitance (Measured in Farads), Reactance and Impedance (Measured in Ohms) and other methods of manipulating the electron flow **allow for the control of voltage and current to drive certain loads**. Engineers can provide current-controlled operation OR voltage-controlled operation of a load based on the designed duty of the load device or sensor circuit.

Diodes and Rectification

Electricity's ONE WAY Check Valve

Managing the Currents



DC Battery Re-Charging:

- If an AC current generator (Alternator) is used to recharge a direct current battery source, the AC must be rectified with a set of diodes to bring all of the voltage pulses above the ground line, producing direct current.
- The resulting voltage is then generally smoothed (Capacitors) and regulated (Resistive voltage dividers) to the desired supply needed to run the circuit.
- In vehicle platforms, this usually all done inside the alternator, which contains the rectifier bridge, diodes and voltage regulator circuitry.
- In modern vehicles, the PCM controls the field circuit based on demand. In older systems, the resistance of the **ALT** light bulb on the dash was used to excite the field, or a resistor was used in the gage assembly on cars with analog gages.
- In older platforms, the voltage regulator was a separate component, not inside the alternator, solid state components (Size) changed that.

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DiagNation

If an AC current generator (Alternator) is used to recharge a direct current battery source, the AC must be rectified with a set of diodes to bring all of the voltage pulses above the "ground" line, producing direct current for the battery plates.
The resulting voltage is then generally smoothed (Capacitors) and regulated (Resistive voltage dividers) to the desired supply needed to run the circuit.
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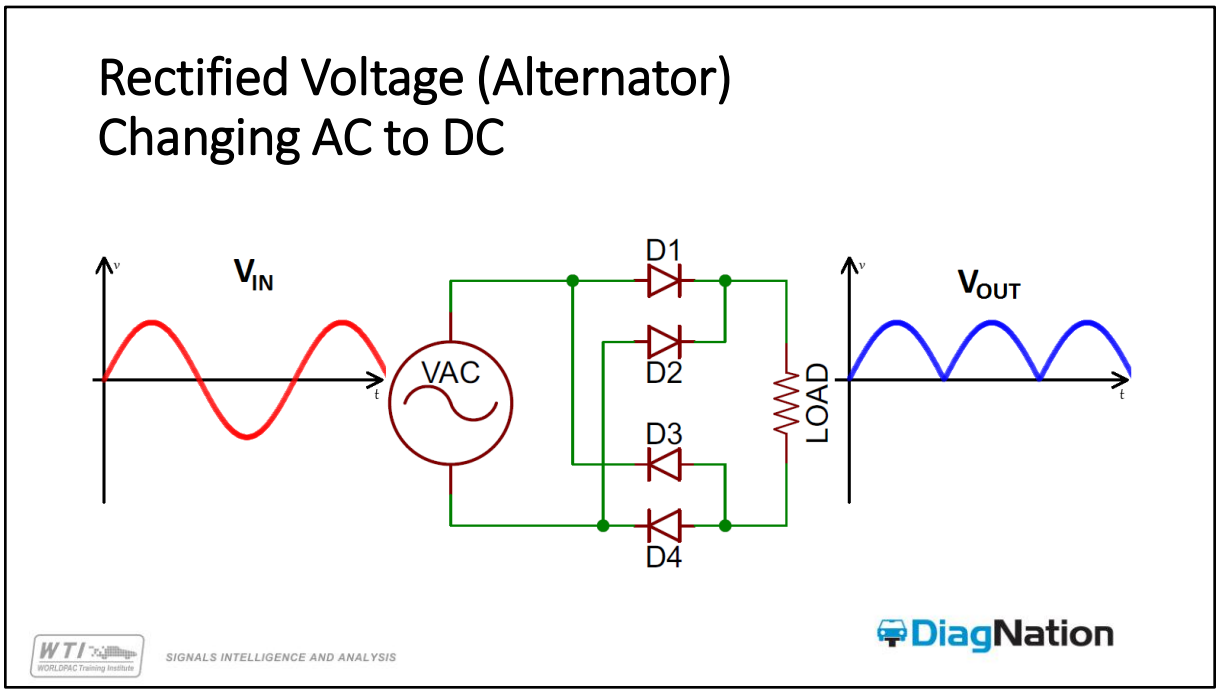
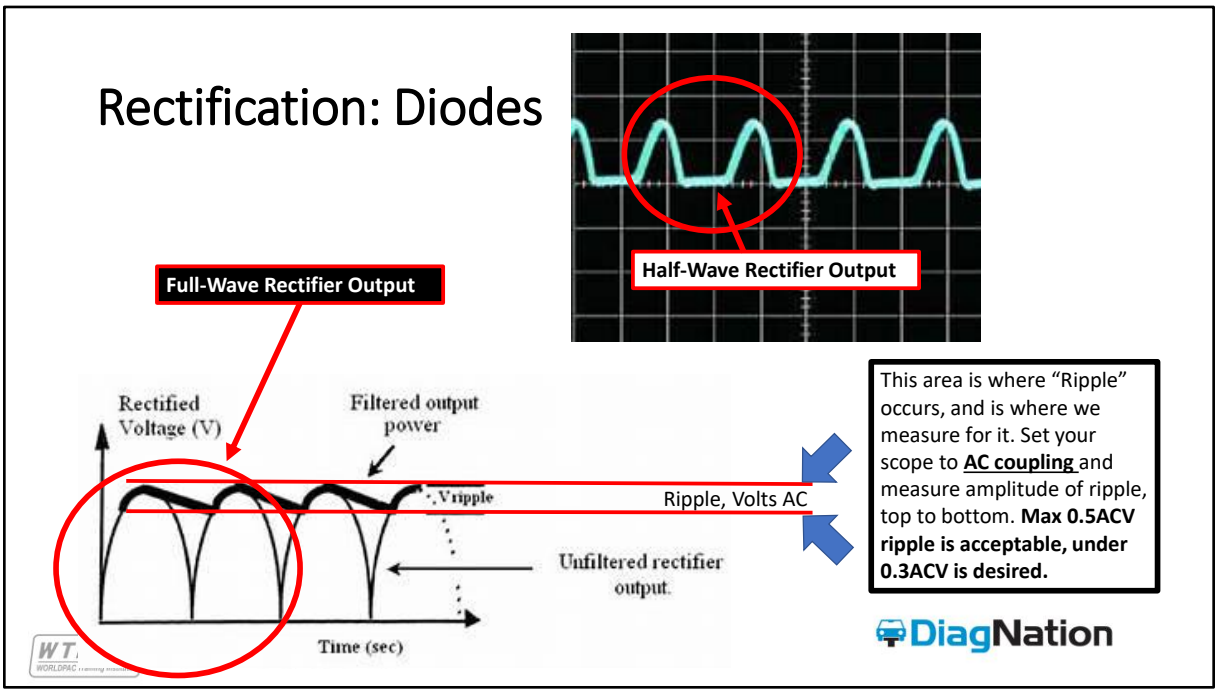


Converting alternating current to direct current for battery recharging and DC use requires a control process called **rectification**. This is accomplished by using diodes, which are devices designed to force current to flow in only one direction. Diodes take many forms, **the original diodes were vacuum tubes**. As engineers began to work with semi-conductors, diodes took the form of transistors, semi-conductor single leg and bridged devices, zeners and many other forms. Diodes always require the tripping of a "turn-on" voltage (Known as Forward Bias) threshold in order to conduct**. In most automotive solid-state computer protection circuits, this is 0.7V**. When voltage dropping computer power circuits at the module, it is NORMAL to observe this 0.7V drop. (This is about the only time this rule of thumb applies, as most circuits should never drop more than 0.5V). Diodes are used to ensure current can only flow in ONE direction, no matter how they are configured in the circuit.



When a circuit is rectified, the voltage and current is smoothed by a capacitor. This provides a "steadier" applied direct current. The capacitor or smoothing circuit is designed to remove **most or all** of the AC oscillations, as seen above. From time to time, the smoothing circuit or diodes may experience a problem where either the rectification OR filtering of rectified voltage begins to exceed design limits. **The resultant AC oscillation remaining on (Riding on) the direct current is known as ripple.** An overly high amount of AC ripple riding on DC circuits will create havoc in digital switching devices and computers. This ripple in our automotive design is usually induced by failed diodes, rectifier bridges or damaged condensers/capacitors in the smoothing circuit. On modern vehicles, this entire function occurs inside of the alternator's circuitry.

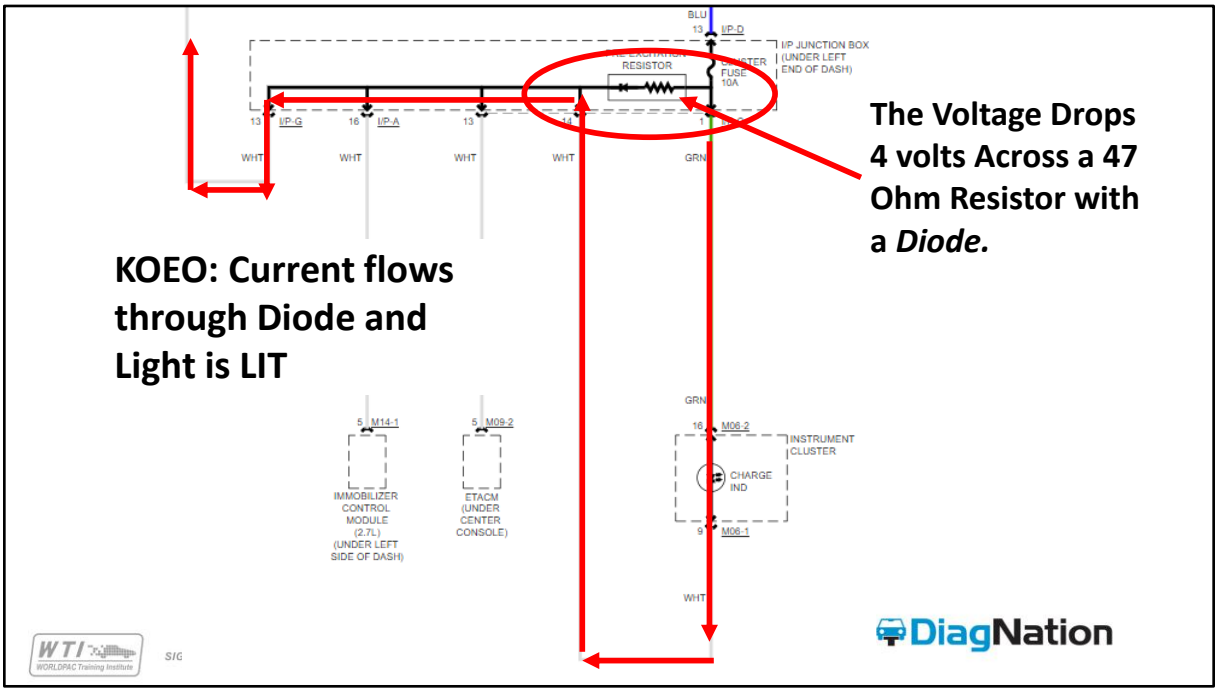


That Nice Kia Glow…

- Charging Light ON
- Alternator replaced (Twice)
- Now Charging Light on DIM, but car is charging fine.
- What's wrong?

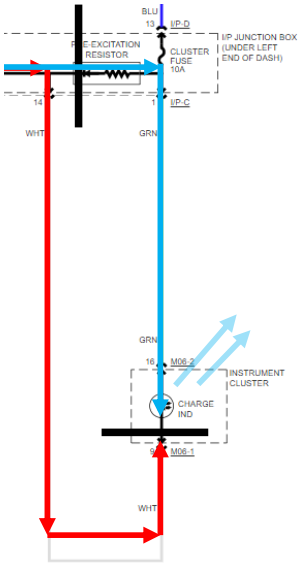
DiagNation

Case Study, Charging and rectification problem, 2009 Kia Sportage



In this example, a new part was unavailable (discontinued). The shop owner decided to dig in and see if it could be repaired. After an alternator (2) had been replaced, they were left with the charging system working fine, but the CHG light glowed slightly after field excitation. As we follow the circuit, we can see that in normal operation the pre-excitation (47 Ohm) resistor drops 4 volts (about what the LED consumes) and when the field turns on. The current is blocked by the 2 diodes in the circuit.
Why was the light glowing dim?

The 4N7001 Diode was leaking causing the faint glow on the cluster



Upon Startup, Current is BLOCKED
When Alternator field is Running

The Charge Light Goes OFF

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DiagNation

The diode at the top, the pre- excitation diode had failed, allowing a small leakage current back across the LED. This was not enough to affect the field circuit once charging, but was a nuisance at night.
The Junction Block was taken apart, the diode tested bad, while the 47 Ohm resistor passed. A new 4N7001 Diode was sourced on Amazon.com, soldered in and: Fixed.
This was a case where understanding diode function, current and voltage measurement fundamentals created a win, where other shops couldn't fix the car.
There are obviously some modules and "smart Fuse Boxes" that we can"t or shouldn't take apart, but it IS nice to score a win like this on the fundamentals and a can-do attitude in testing and problem solving.

From Field Control to Voltage Regulation

- Without voltage regulation, most circuits won't work properly.
- Lighting and power systems fluctuate with generation
- Digital systems would go crazy with voltage fluctuations

- A voltage regulator provides a stable, filtered voltage that can be used by loads and electronics to provide dependable performance.

- **NOTE!!!! Most ALL digital chips run with a Min-Max rating.**

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NOTE!!!! Most ALL digital chips run with a Min-Max rating.

From Voltage Regulation to in the Box (12v-5v Supply rails and grounding component specific

- The boards in most all solid-state electronics today work on the same regulated voltage as car computers.
- Once we get past the power supply, rectification and regulation, they all work exactly the same.
- These regulated voltages are typically bussed together inside the module.
- Critical ops systems will have their own dedicated buss.
- There are often SEVERAL regulated voltage supply busses inside of a modern module

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Resistors

- Resists the flow of electric current in a circuit.
- **The resistive element of any given substance is determined by its molecular structure.**
- Copper (29) and other metals allow electrons to move quickly and freely toward potential from one atomic conduction band to the next.
- Other elements like Carbon, Nitrogen, Silicon and Oxygen contain atomic and molecular structures that provide **collision paths** or partial blocking of electrons in the conduction bands, resisting the flow of electrons.
- Some materials like glass have limited or no structure between molecules to provide a conduction path, these are known as insulators, which do not conduct electricity.

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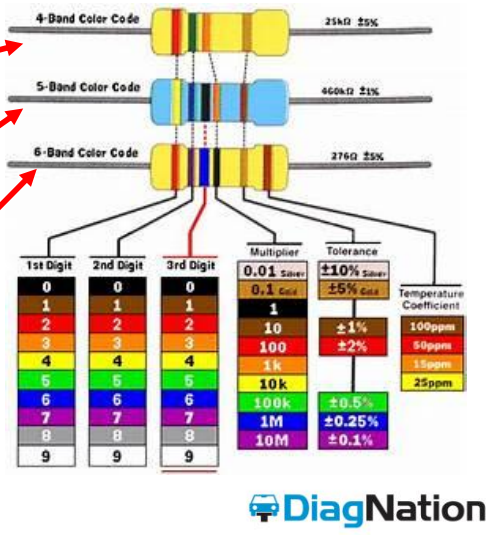
Reading Resistors:

Red = 2
Green = 5
Multiplier = 1k
25 x 1K = 25,000 Ohms or**25K Ohm**

Yellow = 4
Blue = 6
Black = 0
Multiplier = 1k
460x 1K = 460,000 Ohms or **460K**

Red = 2
Purple =7
Blue = 6
Multiplier: Black = 1
267 x 1 = **267 Ohm**



Being able to read and calculate resistor values can be helpful in diagnostics. Understanding how to determine the **resistance VALUE** (Color Band Chart on Right) tells us what the resistance value of the resistor is. The **TOLERANCE band** identifies what the acceptable +- tolerance level is, which determines good/bad criteria during testing.

Example: A 10K Ohm resistor at 5% can read from 9500 Ohms to 10,500 Ohms and be GOOD. But a 10K Ohm 1% tolerance resistor can only read 9,900 Ohms to 10,100 Ohms to test GOOD. A 10K Ohm +- 20% tolerance means that resistor can read from 8,000 Ohms to 12,000 Ohms and be deemed GOOD. These tolerances are ENGINEERED into the circuit.

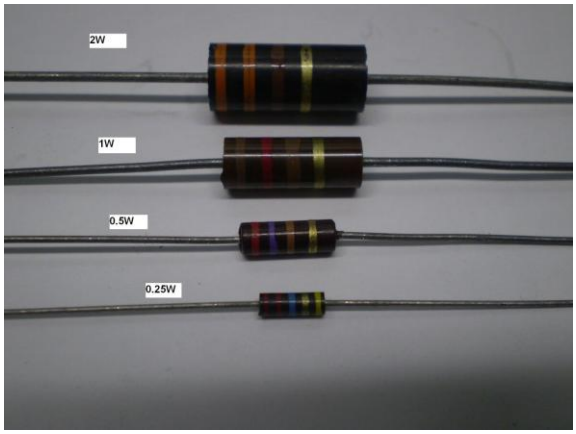
The chart above allows us to read the value of the resistor and test it for good/bad determination.

Resistors: Calculating Wattage Requirements

To Calculate the Wattage (Heat) Dissipation Limits of a Resistor:

P = Power in Watts
I = Current (Amps)
E = Voltage (Volts)

Formula: P= (I x E)
(See Calculation Examples Below)



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DiagNation

The WATTAGE, or how much POWER the resistor can dissipate is important as well. If we choose a resistor with insufficient wattage handling capability, we will likely melt the resistor or other circuit components. ***Resistance always creates heat***, and the resistor must be able to handle (Dissipate) the wattage in the circuit in order to dissipate heat properly.

The formula for figuring this out is the power pie, the formula is: Current X Voltage = Watts. (Power in Watts)= (I x E) Example: if we have 14.7 Volts operating a load at 5 Amps with a running resistance of 2.94 Ohms, we have 73.5 Watts of power in the circuit, in this case we would need a resistor **(or load)** rated for 100 Watts.

In another **low current example**, we have 2.5 Volts CAN bus bias voltage into a load impedance of 60 Ohms, meaning we have 0.041 Amps, or 41mA. 0.041 X 2.5 = 0.1025 Watts, so we would choose a 0.25W resistor for this circuit.

Rule of thumb is to choose resistor wattage so that you are running no more than 75% of that wattage with circuit operating normally. (0.1875w max circuit operating wattage for a 0.25w resistor)

Ohmic Resistance vs Impedance, a Complex Concept and Calculation

- Ohmic resistance, measured in Ohms
- Resistors are used to drop voltage and are used in many different ways.
- Used as the voltage drop device in an oscillator circuit.
- Symbol for Ohms is the Greek Omega ()
- Impedance, measured in Ohms (z)
- Impedance IS resistance, but with the added component of magnetic inductance added.
- This is typically induced into a circuit in the form of a coil, choke, solenoid or other inductive load.

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Lexus Nexus

Nearly Wrecks Us

LS250 with a recurring B2S2 O2 Sensor Range Performance

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DiagNation

The Fault:

- This Lexus had the recurring P0136 for B2S2 Oxygen Sensor Range Performance.
- The shop had put in ***THREE new O2 sensors***
- ***The PCM had been replaced TWICE***
- Checking and Rechecking of the Harness Proved Wiring OK
- This was done with careful voltage dropping with a 2-ohm load.
- The tech ran an overlay circuit, and the fault STILL logged immediately
- What was wrong with this one, could ***SIGNATURES intelligence*** be the answer?

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This Lexus had the recurring P01XX for B2S2 Oxygen Sensor Range Performance.
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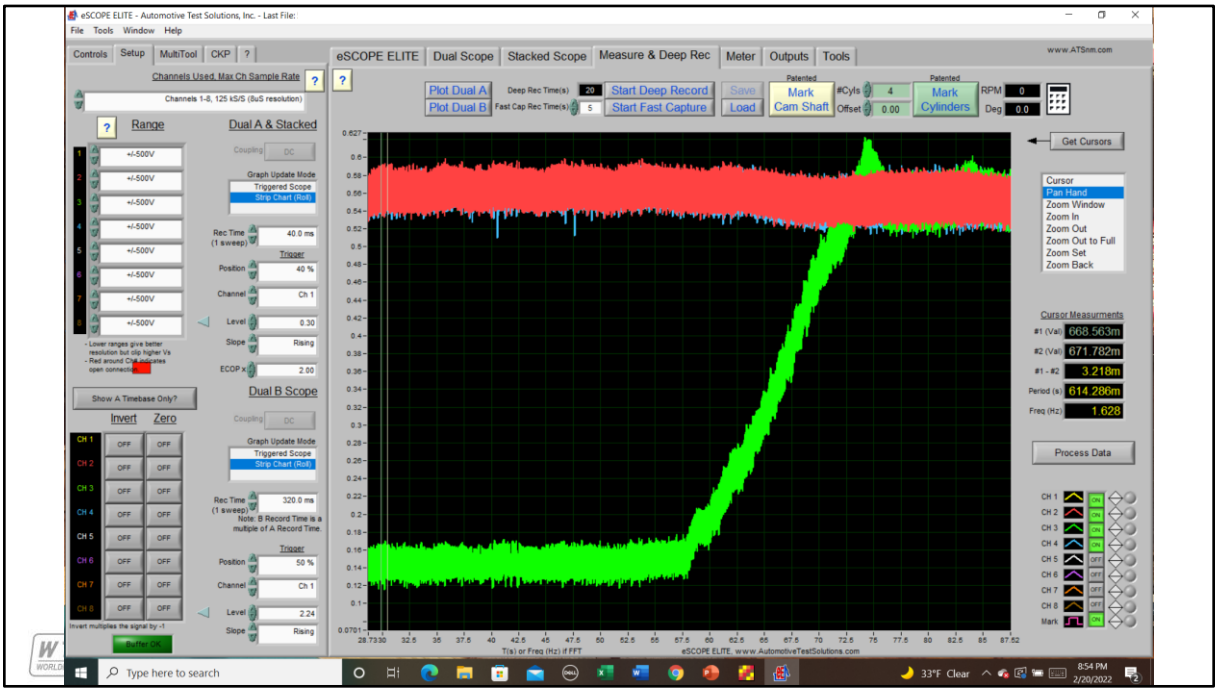
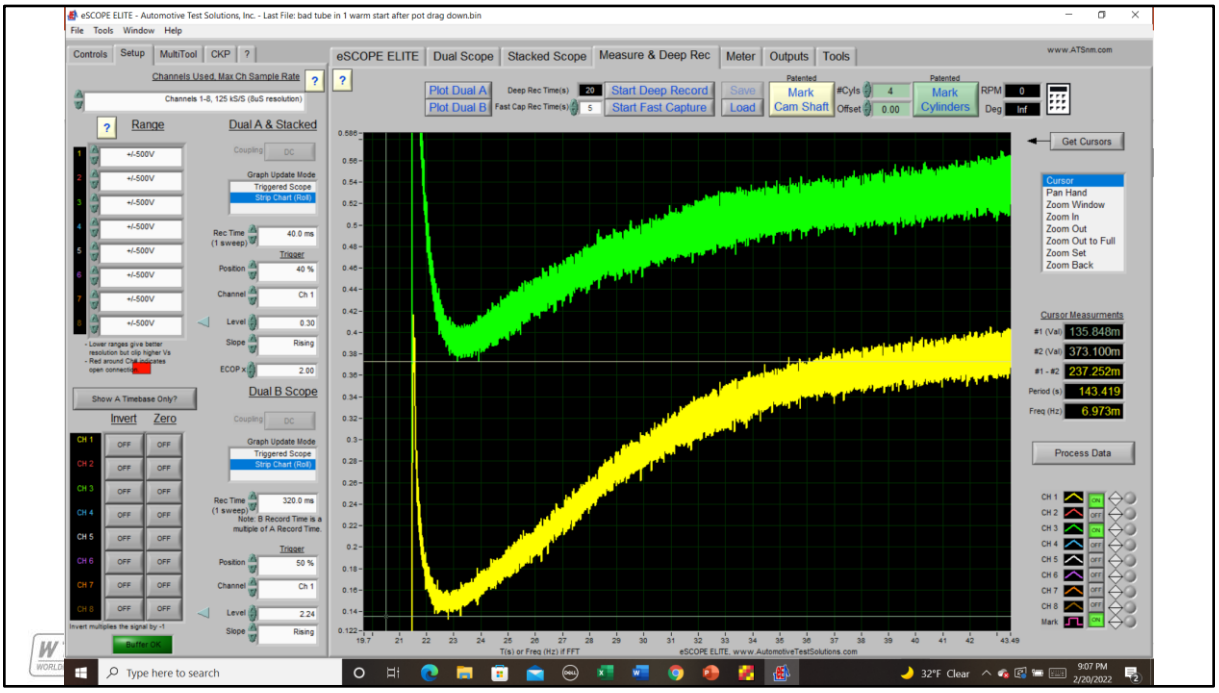


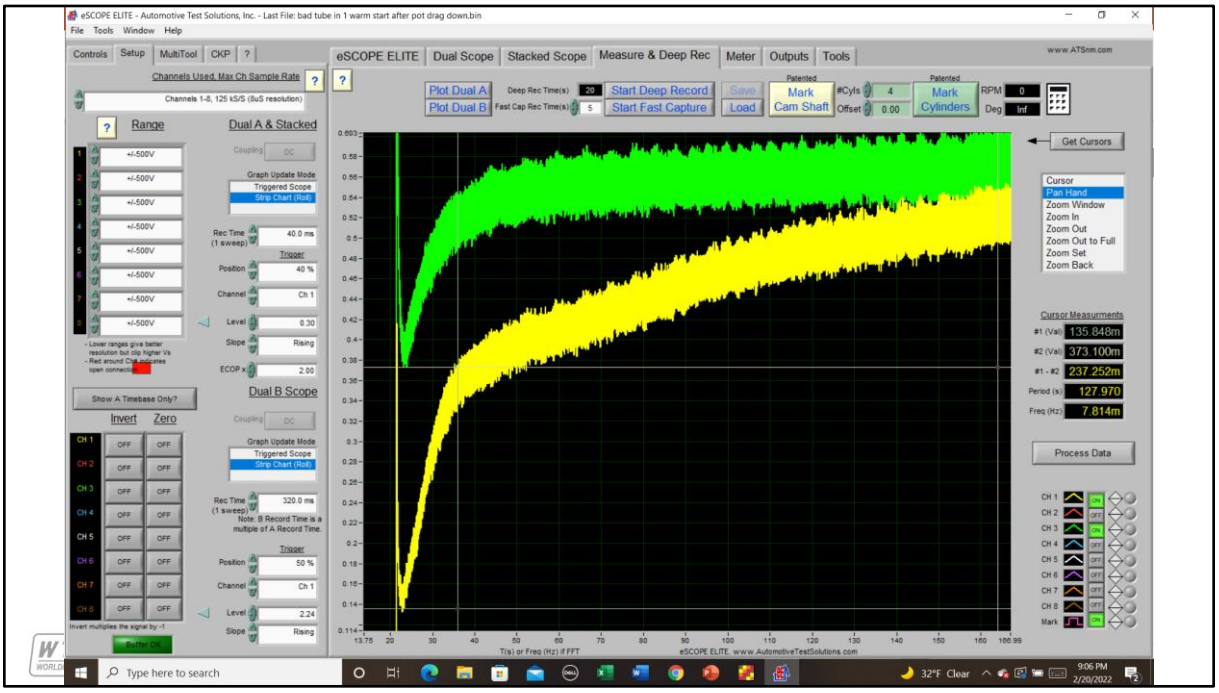
Tech capture of the (Second) Oxygen sensor. Note the voltage that the B2S2 signal line is running at. What sensor do you know that runs on -3 plus volts?

During warmup, the -3 SLOWLY corrects to a semi-normal voltage, however the code sets every time from cold start, regardless of the sensor, PCM or wiring.

This was taken key on engine off, then started and allowed to run.



This capture was from when we looked at the car together on the hotline.
The capture is of the key on switch and warmup of the sensor element. These are the signal lines from each rear 02 sensor.
Two interesting things here, What would cause a voltage drop severe enough to read NEGATIVE DC voltage with the KOEO?
And why is the Yellow trace never getting to the amplitude of the other oxygen sensor?



Here is a shot of the O2 warmup period. When we throw the key on and light up the O2 Heaters, the sensor element begins to react quickly. But the yellow trace is displaying **-3 volts**, while the green trace reads just under **-1 volt**.

What is causing the 2-volt difference in these Bank 1 and Bank 2 sensors?
And WHY are we only getting a Range Performance DTC, and not a hard circuit fault?

Answer: This is not a depositing issue but shows the importance of the heater in the O2's operation. **The impedance of the B2S2 sensor is incorrect for the circuit**.

The 3 sensors were all aftermarket, one from one store and 2 from another.
We advised the shop owner to go to ***LEXUS*** and get a proper sensor for the car.
FIXED.

Capacitors

- Capacitors are designed to store voltage in an ***ELECTRIC field***.
- Capacitors are similar to a battery, in that they both store electrons.
- A battery typically generates its own voltage by chemical reaction where a capacitor only STORES voltage.
- Capacitors will store energy on its plates, when saturated (Full) DC current is blocked until discharged into the circuit by means of voltage drop.
- Capacitors completely block DC current but allow all AC current to pass.
- How the capacitor is wired to the circuit determines what it does and how it performs in the circuit.
- What the capacitor is made of determines its operating characteristics in terms of capacitance (storage, measured in Farads) and max. voltage

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Capacitors are designed to store voltage.
Capacitors are similar to a battery, in that they both store electrons.
A battery typically generates its own voltage by chemical reaction where a capacitor only STORES voltage.
Capacitors will store voltage and impede current flow until saturated and/or discharged.
Capacitors completely block DC current, but allow all AC current to pass.
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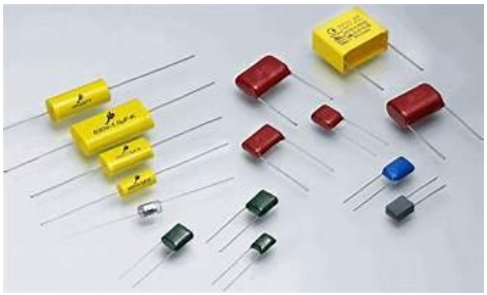
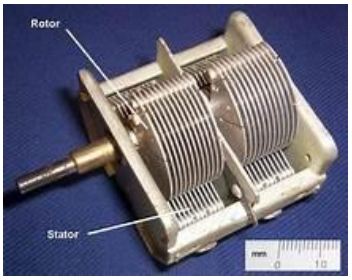
What the capacitor is made of determines its operating characteristics

Types of Capacitors:

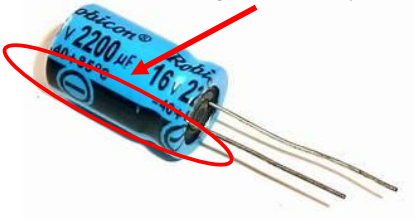
Non-Polarized Film, Poly and Metalized Capacitors





Variable Capacitor, used for tuning circuits

Polarized Electrolytic Capacitor
Used for Power Filtering, Note Polarity Indicator



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There are many types of capacitors for many varied applications and uses.
Capacitors are used for these main primary purposes:

(1) To store voltage for use in a circuit
(2) To Oscillate a circuit, or provide variable resonance against a fixed resistance or inductor (Radio RF Tuning)
(3) To filter power coming into a device (Prevent interference)
(4) To filter or bypass certain frequencies (Hi-pass and Lo-pass filters)
(5) For blocking DC Current and voltage
(6) For shunting a signal or power source to ground

Capacitors are used for all of these purposes and more within automotive platforms.

Electrolytic capacitors must observe voltage polarity markings and be connected to the proper polarity, or fire/explosion can result.

Non-Electrolytic capacitors do NOT need to have the polarity considered in the circuit.

Capacitors

- Capacitors are two conductive plates with dielectric material (Or air) between them.
- The capacitance, or ability to store charge is determined by the size and conductivity of the plates and the nature and construction of the dielectric material between them.
- One plate on the capacitor attaches to the negative side of the source or battery and accepts electrons that the battery or circuit is producing.
- The plate on the capacitor that attaches to the positive side of the battery or source loses electrons to the battery or source.
- When the capacitor's voltage drop reaches a certain threshold, the stored energy instantly discharges into the circuit.
- Because capacitors impede (Store) voltage, when discharged, **current leads the voltage out** by 90 degrees phase.

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DiagNation

Capacitors are simply two conductive plates with dielectric material between them. **The first capacitors** were called Leyden Jars, glass mason jars with conductive foil on either side of the glass. One foil was connected to potential, the other to ground. When the circuit is completed, the stored electrons flowed from the ground side to potential, shocking the experimenter.

The capacitance, measured in Farads – or its ability to store charge is determined by the size and conductivity of the plates and the nature and construction of the dielectric material between them.

One plate on the capacitor attaches to the negative side of the source or battery and accepts electrons that the battery or circuit is producing.

The plate on the capacitor that attaches to the positive side of the battery or source loses electrons to the battery or source.

When the capacitor's voltage reaches a certain threshold, the stored energy instantly discharges into the circuit.

Because capacitors impede (Store) voltage, when discharged, current leads the voltage by 90 degrees.

Uses for Capacitors:

- Power supplies: filters supply line noise from front end circuits.
- Extra start power for motors turning mechanical devices (Provides surge)
- Surge protection capacitors of a value larger than supply voltage can absorb large spikes and smooth the surge into the circuit. (Snubbers)
- Coupling and decoupling of all manner of analog sensor, audio frequency and radio frequency signals.
- Oscillators, timers and many other uses…
- Voltage/Current Bleeder Circuits: These are resistors wired in parallel to discharge high voltage from the capacitors when the device is turned off.
- Charge Pumps

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DiagNation

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Power supplies: filters supply line noise from front end power circuits.
To provide extra start power for motors turning mechanical devices (Provides surge)
Surge protection Capacitor value larger than supply voltage can absorb large spikes and smooth the surge into the circuit.
Coupling and decoupling of all manner of analog sensor, audio frequency and radio frequency signals.
Oscillators, timers and many other uses…
Snubbers: Used to absorb high voltage spikes when inductors impede the current flow to protect switching devices and power supplies.
Voltage/Current Bleeder Circuits: These are resistors wired in parallel to discharge high voltage from the capacitors when the device is turned off.

Inductors (The electrical Inverse of the Cap)

- Inductors impede current flow and allow voltage to pass unimpeded.
- Inductors are typically coils of wire wound around a core. When a current is applied, the coil impedes current flow by creating a magnetic field of equal amplitude but opposing the current flow of the source current.
- Inductors are used to control current flow in resonant oscillating circuits.
- CAN bus nodes and other electronics in vehicles use inductors, otherwise known as “Chokes”
- Inductor’s current Impedance is measured in henries, IE: 680uh (Microhenries) and indicates how much magnetic current can be blocked.
- **Voltage leads current out** by 90 degrees phase after flowing through an inductor.

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DiagNation

Inductors:
Just like resistors and capacitors, an inductor can take several forms. There are both fixed value inductors and variable inductors. An inductor is measured in units called Henries. There are multipliers used, just like with resistors and capacitors, IE: Ohms, Kilo Ohms, Meg Ohms and Gig Ohms…

With inductors, we have base unit of Henries, then Millihenries and Microhenries, Picohenries, etc.

Written as : 25H” (Henry), “25mH” (milliHenries) or “25uH” (microHenries) or “25pH” (Picohenries)

Inductors and Inductance Defined

- An inductor's physical resistance to ***changes in CURRENT*** is measured in scaling units of henry.
- The larger the value of L (Inductance in henry) the LOWER the ***rate of change*** of current occurs in the circuit.
- Inductors can be used for multiple purposes and are built different ways:
- Air-core and steel core inductors (Radio coils, IF Transformers)
- Magnetic inductors, solenoids, transformers
- Torroidal for filtration and oscillation
- Power chokes (Smoothing and Filtering)

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Transformers:

- The first commercially functional transformer was invented in 1885 by William Stanley, who worked for George Westinghouse.
- Transformers are 2 separate coils of wire wound around a core, a primary field and a Secondary field.
- When the Primary is energized, magnetic energy builds in the circuit, voltage and current are magnetically induced on the secondary windings.
- Transformers can be used in AC or DC current systems.
- The Ignition Coil is a step-up style transformer.

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Transformers

- Transformers allow currents to be passed from one coil to the next, without any mechanical connection whatsoever.
- This is handy for amplified power transfer, audio AF and radio RF, oscillation, switch gear, providing varying voltages and more.
- The 3 primary types of transformers are:
- Step Up Transformer (Boost)
- Step Down Transformer (Buck)
- Isolation Transformer (Pass-thru voltage and current, for safety)
- Hybrid and EV cars use Buck-Boost transformers for power management

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Transistors, FETS, IGBTs

The Electronic Switch, Signal and Power Amplifier and Signal Processor

The 3-Legged BEAST

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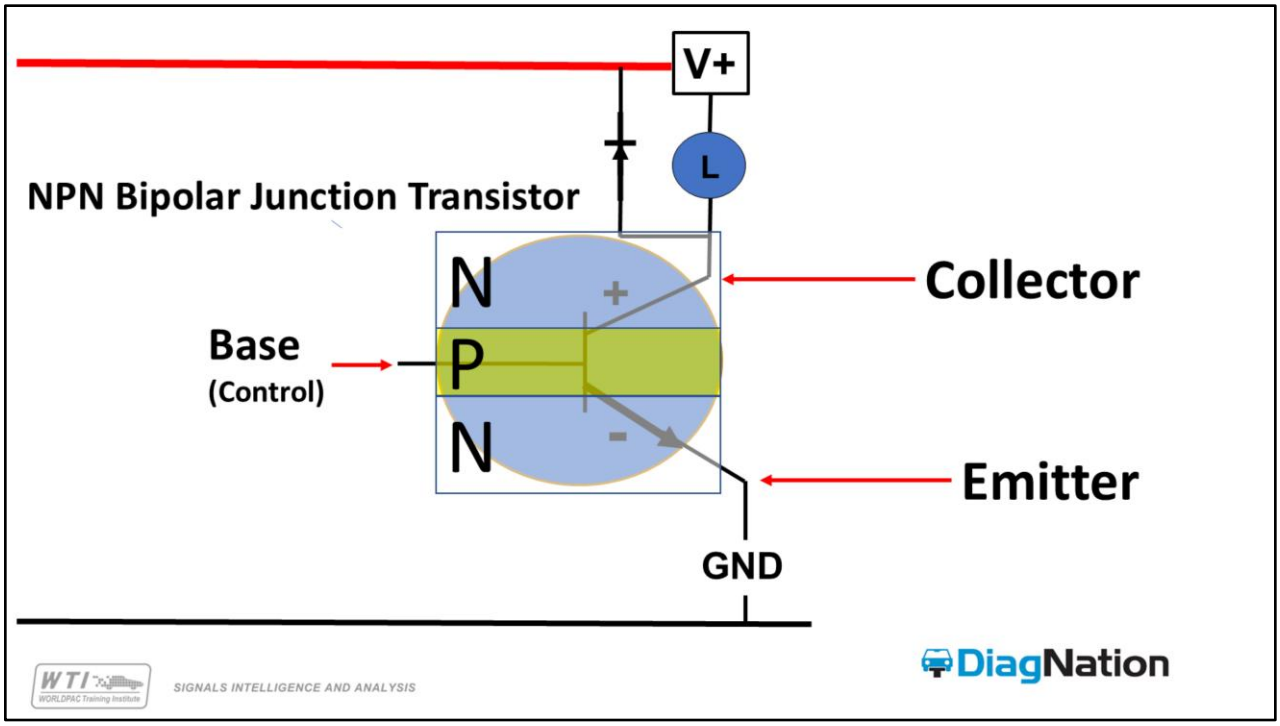
DiagNation

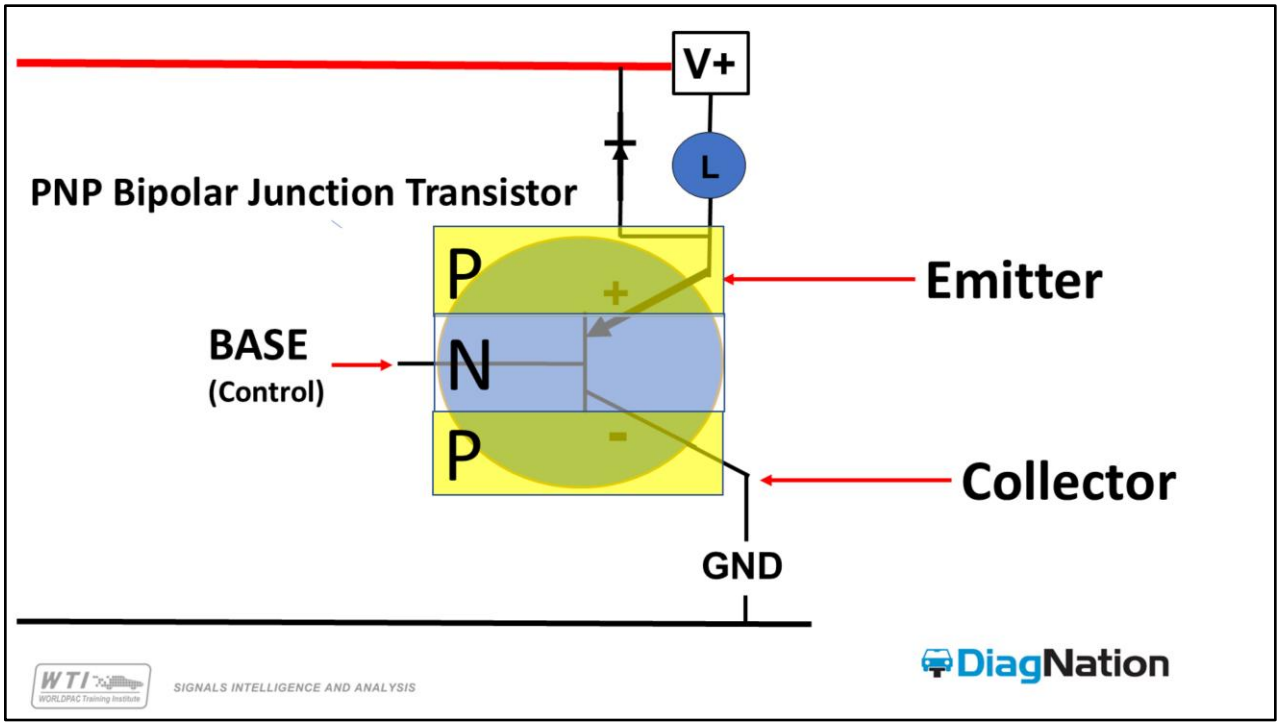
Looking at a transistorized circuit driver along with its IC chip can help our understanding of what we are actually testing for and looking at when analyzing a driver for circuit and device performance and the driver's control circuits, which ARE 2 entirely separate things.

Knowing this, and understanding how to interpret the driver properly can be hugely beneficial to get your diagnostic RIGHT and COMPLETE when analyzing system driver hardware.

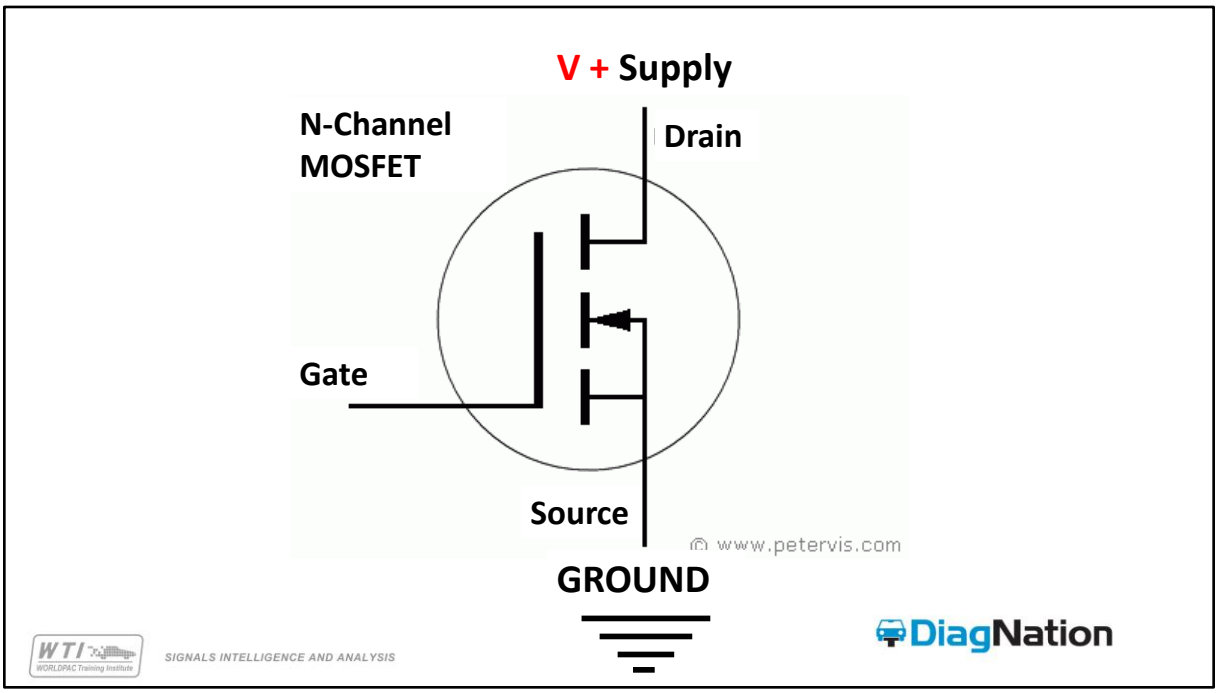
A combination of either Resistor/Capacitor, (RC circuit control) or Resistor/Inductor (R/L circuit control) or both, are used to control an IC chip and driver in a module.
CAN networks use R/L on one side of bus and R/C on the other to provide phase balance to the CAN lines.



A transistor can take many shapes, forms and configurations. They range from metal to plastic, huge to nano-tiny and along with the components to run them, transistors make up 80 percent of all electronic functionality. This includes everything from signal processing to amplification, to creation of RF to high speed current switching (PWM)
The three terminals, Base, Collector and Emitter are as follows:
Base = Control and signal input for transistor
Collector = The potential source
Emitter = The SINK for the load to ground
The location OF the load (Positive or negative side) and how it is wired into the circuit depends on engineering and whether it is intended to be a current or voltage-controlled load device.
Whether the circuit is current or voltage controlled is predicated on what you feed the BASE with, either voltage, or current. (PHASE)



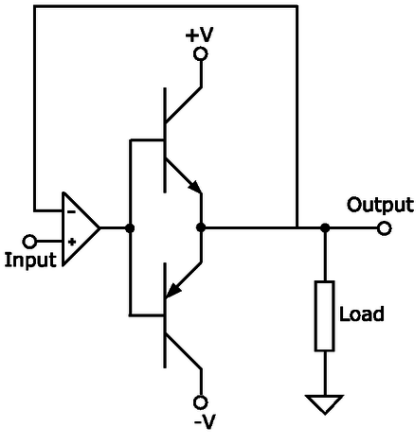
The NPN, indicating Negative-Positive-Negative, also refers to the configuration of the transistor's DOPING material, the semi-conductor material used in it's construction.
The P indicates the material is doped with Boron (Ions) to provide holes to accept electrons.
The N indicates the material is doped with Arsenic or Phosphorus, which provides free mobile Electrons.
But since the P-doping provides holes for attraction of Electrons (Positive Potential) and N-doping provides Electrons, Positive and negative are still a good way of thinking of the terms.
In an NPN application, the base (the P-Doped side) must be at a higher potential than the emitter related to ground. This (BIAS) control of the transistor ensure no conduction until forward biased at the base. This is usually (Universally) 0.68 (or0.7) V, but in some applications, we can see a 0.4 forward bias, up to as high as 1.3V in certain applications.
MOST of the transistors and drivers we deal with in Automotive will have a 0.7v forward bias (Turn-on voltage or equivalent current)



With FET devices, the source and drain names are based in electron theory:
Gate: The "Valve" that turns it on or controls BIAS
Source (Of Electrons)
Drain (Electrons drain TO)

N-Channel FET configuration similar to NPN transistor
P-Channel FET configuration similar to PNP Transistor

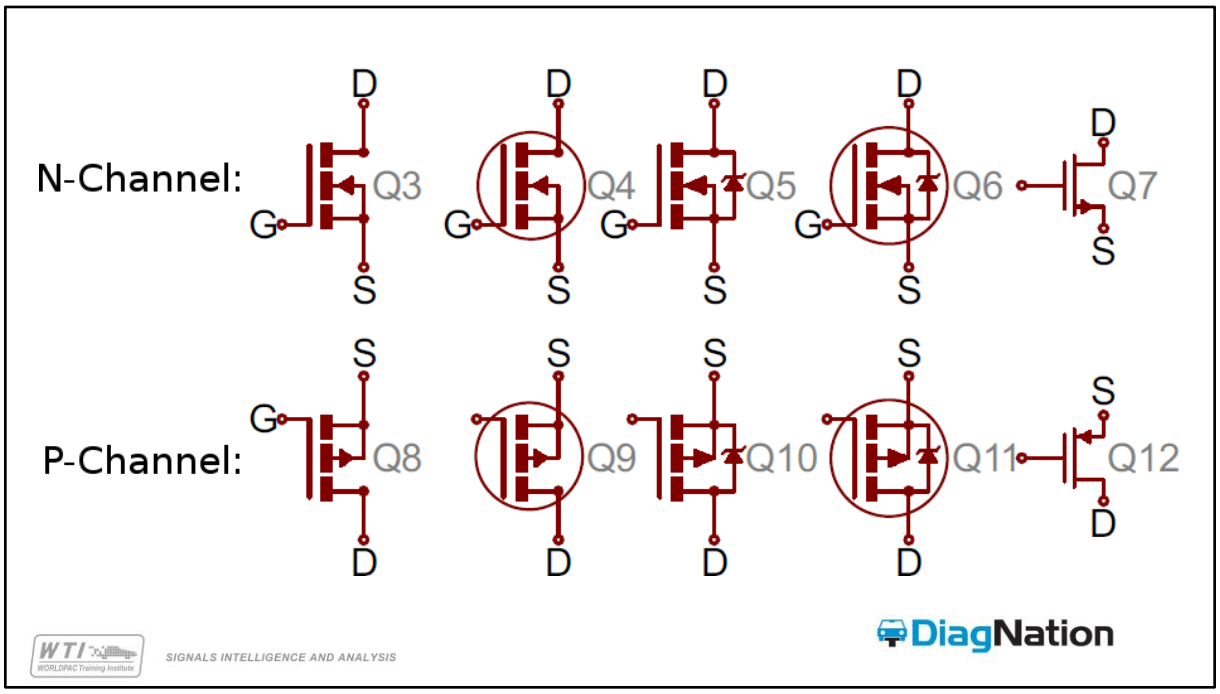
Transistor Configurations in the Circuit



SIGNALS INTELLIGENCE AND ANALYSIS

DiagNation

(From Dave Astel's Push-Pull Diagram:
Since a PNP transistor works more or less the opposite of an NPN, it can be used where negative voltages are involved. One such example is in amplifying an AC signal for driving a speaker. A speaker moves air to create sound. While you can use a speaker with a DC signal (that varies between 0 and some positive voltage) that pushes the speaker cone outward (and relax to it's neutral position) to create a sound wave, you can create louder sound if you also pull the cone back.
In an Automotive application, a push-pull could be used to drive a PM motor that required positive and negative control. (3-Phase)
In the Diagram above by Dave Astels, when the input is positive, the NPN transistor conducts and drives the output toward +V. When the input is negative, the PNP transistor conducts, driving the output toward -V.

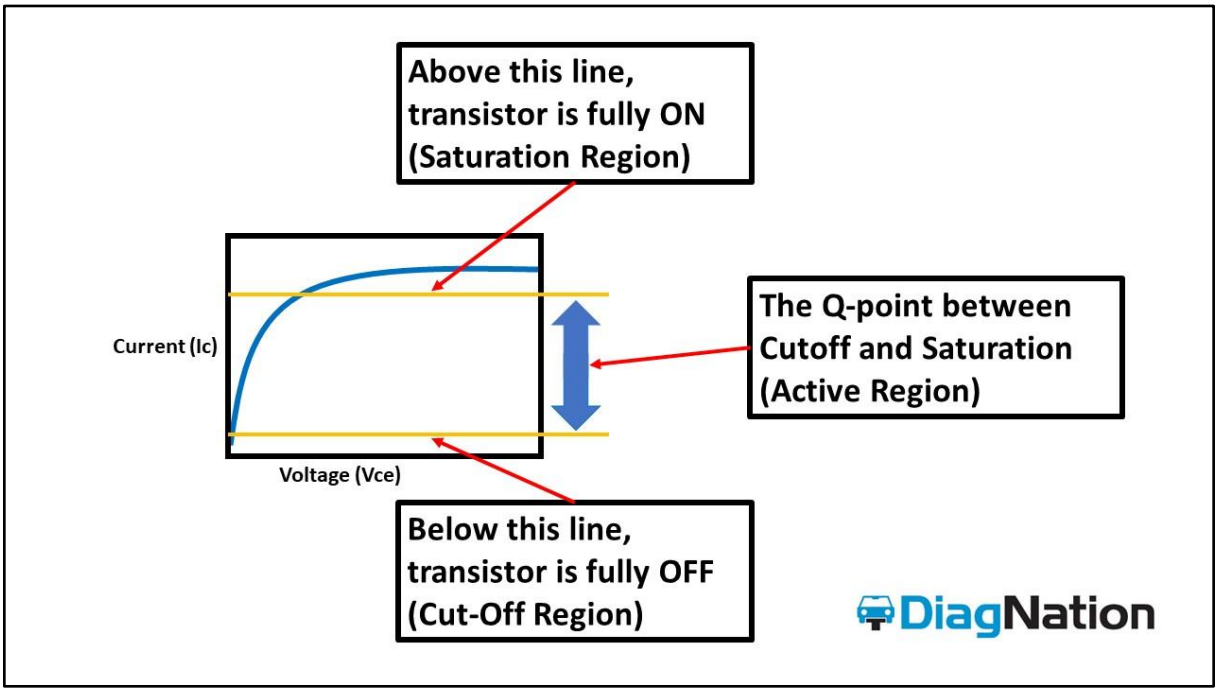


This graphic shows a bank of different style N and P-Channel FET devices.

FETs, (MOSFET) (CMOS) (IGBT) etc. are used for high-current circuit drivers, ignition coils, solenoids, motors and such.

IGBTs, which are insulated GATE Bipolar Transistors are used for High-speed, high-current power switching. Our 48v to 300+ Volt Hybrid and EV vehicles utilize the IGBT in the Hybrid Power Module.

FETs are also used for signal processing and amplification.

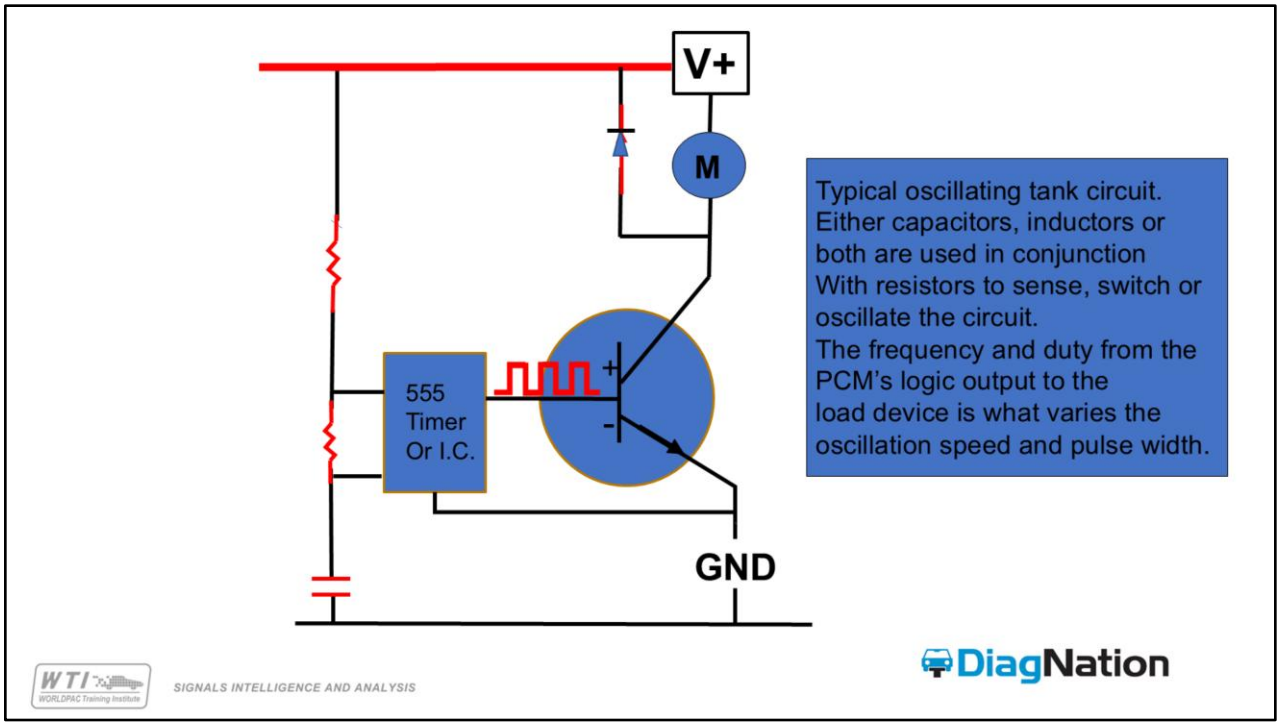


Transistors can be used as on-off switches, (PWM) or as signal amplifiers or processors. Combinations of thousands of these, configured properly for the logic desired, makes up modern digital signal processors.

The transistor is considered fully off in the cutoff region
The transistor is considered fully on in the saturation region.

The TIME it takes to switch the circuit on and off is directly related to the resistor-capacitor-inductor values AND the transistor's switching characteristics when selected to run the circuit.

When these values begin to drift in a IC controlled module, strange and ghostly things happen.



Typical oscillating tank circuit. Either capacitors, inductors or both are used in conjunction with resistors to sense, switch or oscillate the circuit.
The frequency and duty from the PCM's logic output to the load device is what varies the oscillation speed and pulse width.

We can create this driver with a simple transistor, capacitor and variable resistor and some voltage to drive it.

Case Study:

Sprinter Shenanigans

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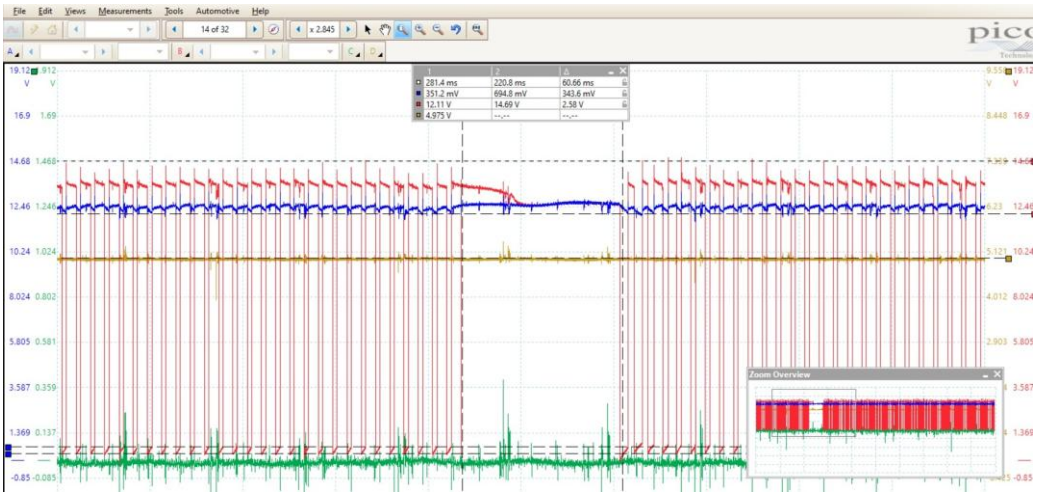
DiagNation



SIGNALS INTELLIGENCE AND ANALYSIS

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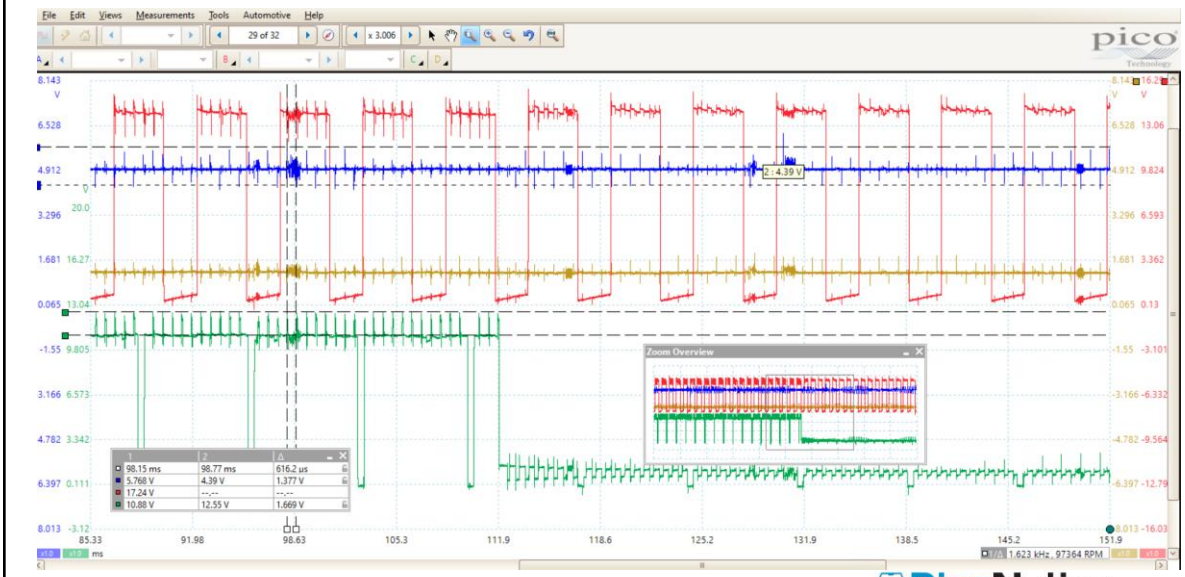

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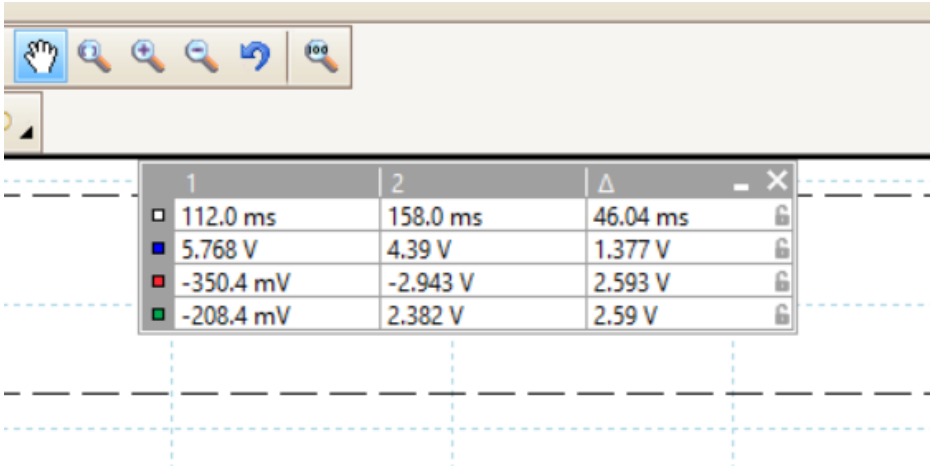

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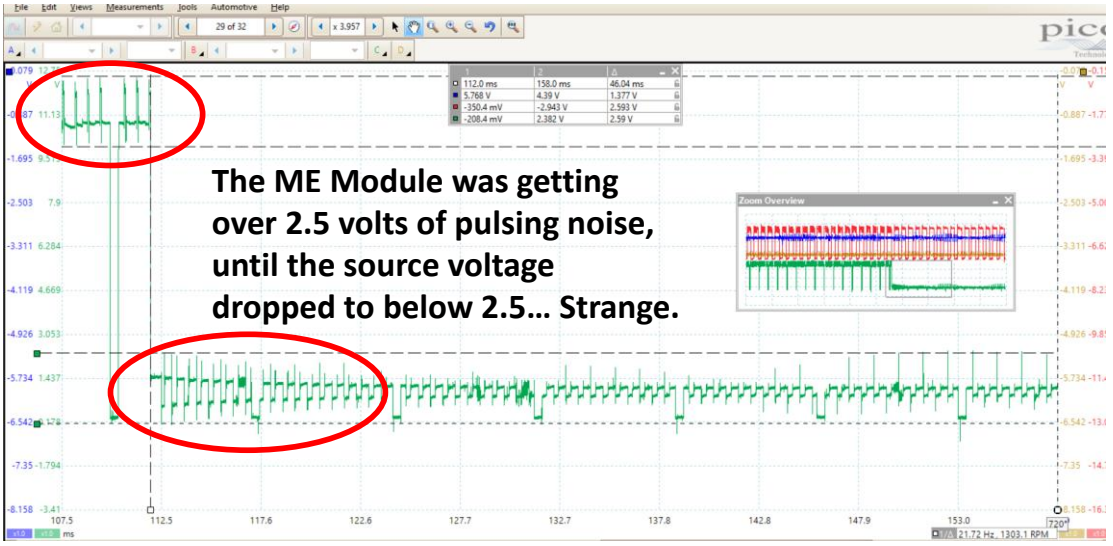

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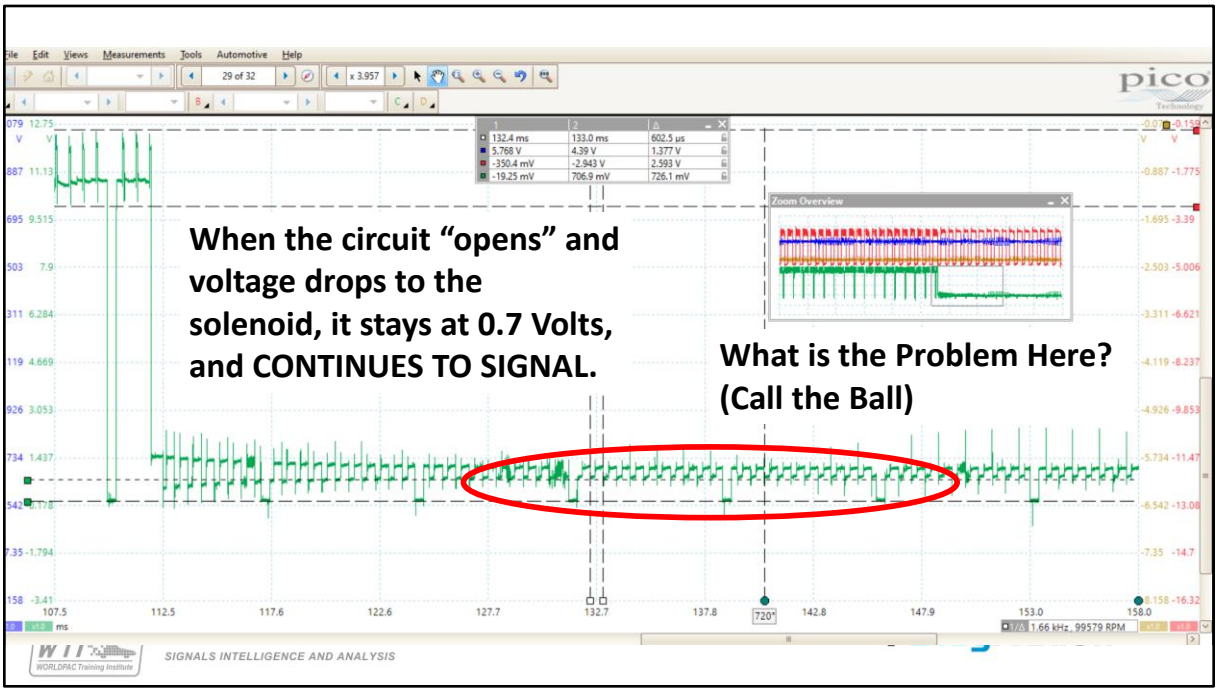
When the circuit “opens” and voltage drops to the solenoid, it stays at 0.7 Volts, and CONTINUES TO SIGNAL.
What is the Problem Here? (Call the Ball)
SIGNALS INTELLIGENCE AND ANALYSIS

RC, LC and RLC Circuits in Vehicle Electronics

- **RC Circuits = Resistance/Capacitance Circuit:** This method is used to control voltage and create duty cycle – controlled PWM signals. The resistance (Fixed or variable) is used to control the charging and discharging of the capacitor.
- **LC Circuits = Inductance/Capacitance Circuit:** This method is used to control current flow in a circuit to oscillate the circuit between voltages. The capacitor is charged and discharged by controlling the current flow in the circuit.
- **RLC Circuits = Resistance/Inductance/Capacitance Circuits:** These circuits utilize resistors, chokes (induction coils) and capacitors to provide switching or oscillation.

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What Makes it All Tick Then?

- Ok, so capacitors store voltage
- Inductors store current.
- Resistors resist voltage and therefore current.
- Transistors Drive loads and process signals.
- So WHAT makes the oscillator TICK?
- **Time. Simple as that.**
- In electrical engineering, all components, chips, capacitors, chokes all of them, are configured to work over a period of TIME (t).
- **This is known as a Time Constant, or (t_c) in engineering formulas.**
- A capacitor, depending upon the size of its plates and the material it is made of takes a certain amount of **TIME** to charge from zero volts (Empty) to saturation (Full).
- The time it takes to charge any given capacitor is used in conjunction with load resistances designed to exploit this time.

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Signal Processing:

Manipulating a voltage or current to alter it's characteristics or to confer data

- Creating or modulating a signal
- Crankshaft and Camshaft Sensors
- Signal CREATED by varying the magnetic field by way of a reluctor
- Signal MODULATION is set to the rotational position notches on the reluctor

Transport That Signal: Combine on Carrier of some sort.

- Wired (***Driving voltage and current across a sensor, a load***)
- RF (Driving voltage and current to or from a receiver / transmitter)
- AF (Driving voltage and current to a speaker or transducer)

- Reforming and communications messaging
- Outputs and Output power controls: **DRIVEN and Modulated**

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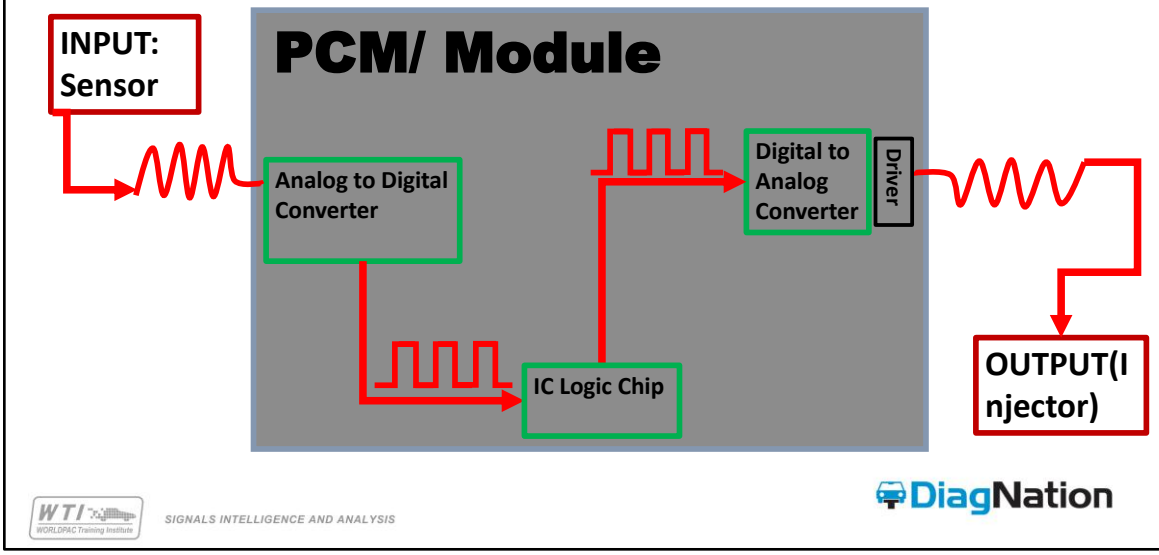
Sig Processor ADC, DC/DC and DAC Conversions



Inside modules, sensor signals are translated from the analog world (Our world) to the digital world (The DME's world) by a device called a comparator. The comparator is made up of multiple transistors, networked in such a way as to be able to interpret that analog voltage VERY accurately and VERY quickly using Strings of transistors configured to split down the voltage in chunks, to target and interpret the analog voltage using feedback circuits.

Comparators, for our purposes, provide an almost instantaneous conversion of that analog voltage to digital binary information for the DME's logic chips to use. The converted data is then processed through the programming algorithm's truth tables and the TCV/ETM will then be driven by the processor's input to the ETM's H-bridge controller, which contains the current drivers.

Conversions Occurring to Produce Data

- A/D via Flash Comparator (Fastest, Comparators now built in to IC chip)
- A/D via Comparator/Biased Voltage or Digital Ramp (Slowest)
- A/D via Successive Approximation (Most common in Automotive)
- Micro-transistors are utilized for comparator switches.
- The Hexadecimal and/or Binary conversions are then analyzed (Software reading switches) by accessing look up tables and truth tables programmed into the software to determine logic decisions.
- ***ALL outputs are PROGRAMMED RESPONSES to input information!***

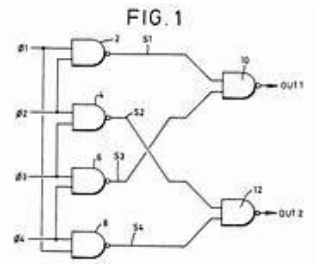


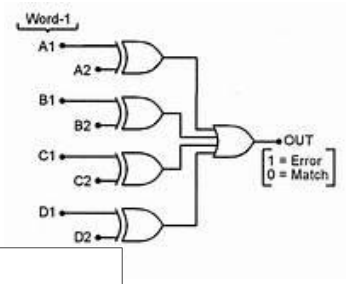
SIGNALS INTELLIGENCE AND ANALYSIS

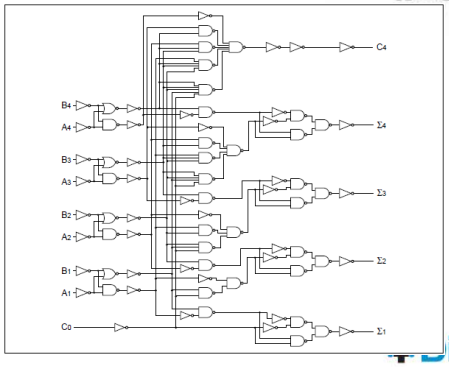
DiagNation

Analog/Digital conversions via Flash Comparator (Fastest, Comparators now built in to IC chip)
Analog/Digital conversions via Comparator/Biased Voltage or Digital Ramp (Slowest)
Analog/Digital conversions via Successive Approximation (Most common in Automotive)
Most A/D converters need a D/A conversion to feed one leg of comparator. Micro-transistors are utilized for comparator switches.
The Hexadecimal and/or Binary conversions are then analyzed (Software reading switches) by accessing look up tables and truth tables programmed into the software to determine logic decisions.
It is very important to remember that ALL outputs are *PROGRAMMED RESPONSES* to input information!

Comparators







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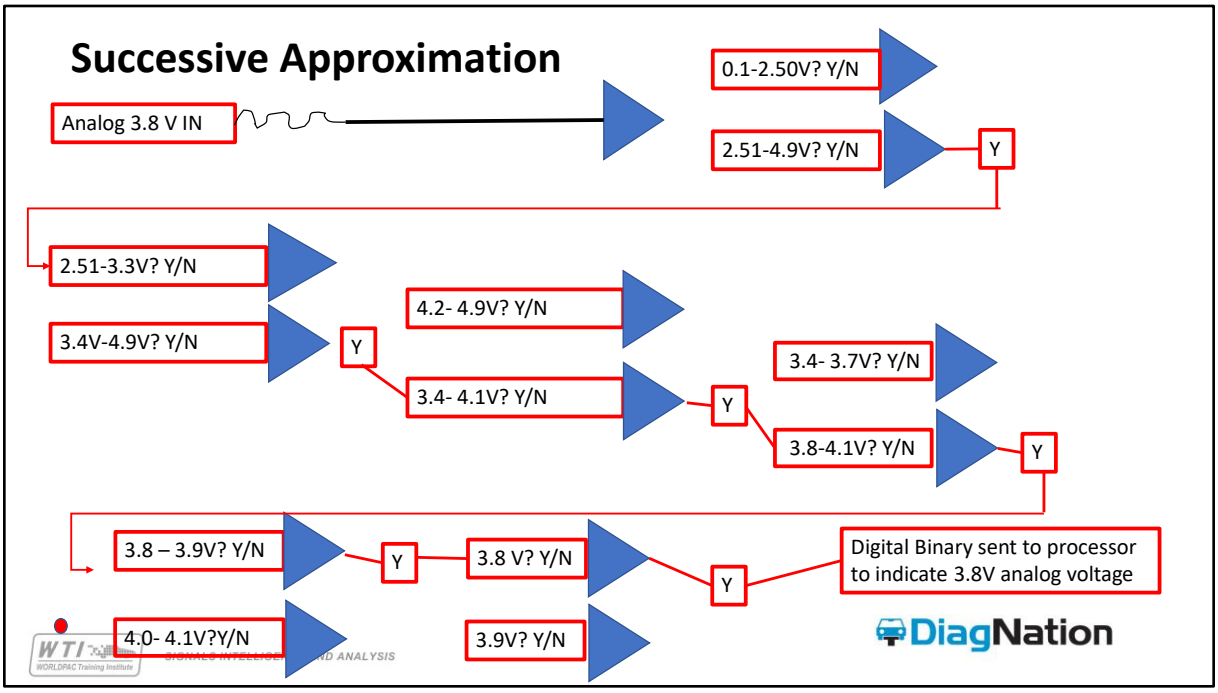
DiagNation

Comparators take an analog input signal (Voltage) waveform from a sensor, transducer or output load's feedback circuit and converts the analog signal to a digital value, very quickly. In our industry's control modules, the successive approximation comparator has been the most common type used to date. However, as technology advances and computing, conversion and processing speeds increase to accommodate X-By Wire applications, flash comparators are becoming more common in modern controllers.

To understand the logic of a successive approximation comparator, consider a very fast game of If-Then or True-False, where an analog voltage waveform is applied to a number of transistors in sequential groups, where each transistor in the stack is biased to the output of another. As the transistor stack analyzes these output voltages, a digital binary guessing game ensues, where the processor checks the analog signal waveform against **any possible** combination of binary representations of that signal. When the logic chip has determined that the digital binary representation of the analog waveform's signal is correct, the data is then compared to the software's truth tables and the IC prepares an output response.



The graphic above explains the basics of how an Analog to Digital successive approximation – type A/D conversion would occur, when a 3.8V analog signal is processed by a comparator. Because electricity flows at the speed of light, as fast as the transistors give up their information to the next, the signal is processed and converted to digital binary data in micro-seconds.

The successive approximation sequence is started by dividing the voltage input range by 2, then analyzing the true-false answer. (Voltage (and current) **will continue to travel through to the next transistor's division** if
TRUE, **voltage will NOT continue to flow from the FALSE comparator**. In this way, the signal keeps dividing itself in half as its voltage travels through the bank of comparator transistors, until it has been exactly pin-pointed by the comparator. This final data is passed along to the software's truth tables for analysis and output control.

Once the analog voltage has been converted to a digital value, the processor can now use this signal to make decisions and issue output responses, based on the software's truth tables and programming.

Analog-Digital Conversion (IN) to Digital-Analog Conversion (Out)

To Extract information from a signal

- Processing Analog Signal IN
- Wired Analog Signal (Voltage, Sine Wave, Square Wave, etc…)
- RF Wave (With Digital Packet)

- Decoding
- Successive Approximators, (Analog to digital)
- Taken down to “Language” (Programming, algorithms)
- Use (Digital Logic)
- Truth tables
- **Output Command or Signal**

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Outputs

- Digital to Analog Conversion Takes Place in the MCU.
- A logic decision in the chip outputs signal to a device driver and the circuit operates, OR,
- Comms: a digital output command or information packet is formed by the Medium Access Layer.
- The node then transmits the signal to the balanced antenna (Twisted Pair)

- Power Signal Output: (Coil, Injector, EVAP, ETM)
- Devices: H-Bridge, MOSFET, IGBT, RF Transmitter

- Analog Output to Load Device VIA
- Circuit board Termination
- Module Connectors and PINS
- Wiring (Transport) to Load

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Module Connectors and PINS
Wiring (Transport) to Load

Data Structure Similar By Domain

- Each subset of the vehicle requires data, processing and logic outputs.
- As such, it can be assumed that the availability of data will satisfy the ***basic needs for diagnostics*** within that system. (In theory…)
- Because modules share data via data bus lines, we need to be aware of potential corruption when things appear strange or unexplainable.
- In order to use data effectively, it is helpful to have a fairly strong understanding of the ***THEORY of the system*** you are analyzing.
- We can become ***buried in data to "analyze"*** and it is not difficult for even the best tech to "Out-Tech" themselves in this day and age.

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Each subset domain of the vehicle typically requires it's own data, processing and logic outputs.
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Because modules share data via data bus lines, we need to be aware of potential data transmission OR processing corruption when things appear strange or unexplainable.
In order to use PID data effectively, it is helpful to have a fairly strong understanding of the ***THEORY of the system*** you are analyzing.
We can quickly become ***buried in data to "analyze"*** and it is not difficult for even the best tech to **"Out-Tech"** themselves in this day and age. Most tech support calls, once solved, will usually reflect this, as most solutions turn out to be basic and not complex in nature.

PID: Parameter In Data, Parameter ID

- Data PIDS give us a view of the *physical condition, state of operation or status* of any input or output device controlled by an MCU (Module).
- Physical data is encoded and decoded by analog to digital, digital to analog and digital/digital conversions in the micro-controller's logic ICs.
- Conversions are from analog to binary or hex, used by the PCM and back to binary again to be transmitted over the data bus for use by other modules.
- There are several conversion methods used by a typical automotive controller. These signals are converted, used and acted upon in ***Microseconds***.
- **Most of these signals today are clocked to the computer.**
- In diagnostics, it is CRITICAL to remember the garbage-in-garbage-out rule when analyzing PID data.

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Data PIDS give us a view of the *physical condition, state of operation or status* of any input or output device controlled by an MCU (Module).
Physical data is encoded and decoded by analog to digital, digital to analog and digital/digital conversions in the micro-controller's logic ICs.
Conversions are from analog or binary to hex, used by the PCM and back to binary again to be transmitted over the data bus for use by other modules.
There are several conversion methods used by a typical automotive controller. These signals are converted, used and acted upon in ***Microseconds***. (This is why we often have better luck seeing circuit issues with a scope, not a scanner…)
Most of these signals and data transmissions are clocked to the computers in the network, or in the case of FlexRay, clocked to the data packet itself.
In diagnostics, it is CRITICAL to remember the **garbage-in-garbage-out rule** when analyzing PID data.

Important Thoughts About PID Data

- Although normally “dependable”, PID data still needs to be verified from time to time.
- Because these data can be altered or corrupted, confirming data by way of PHYSICAL TESTING AND MEASUREMENT must be performed.
- Because the engineering of the system involves physical and moving parts, sensors, modules, wiring and software (and… human interference), we can prove or disprove ANY data by way of physical properties testing.
- PIDS vary by OEM, model, year and “Era”… as do scanners. Some OEMs are great at providing data (Toyota), others, not so much. (Nissan)
- In ‘08 and up models, we have seen quantum leaps in the availability of actionable data in all vehicle domains.

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DME/PCM/ECM Typical Data Sets

- **Fuel Control:** Injection, Supply, Fuel Trims, O2/AFR Data
- **Ignition:** Coils, Drivers, Feedback Data, Voltage Sense, Misfire
- **Exhaust:** DPF/SCR, NOx O2/AFR, Catalytic Converter, Temp Sensors
- **Air Controls:** MAF, MAP IAT, VGT, IAC, ETM, IRC, APP, TPS
- **Outputs From Feedback Control:** Ignition Coils, EVAP, INJPW, ETM Duty, Fuel Pump Duty, Cooling Fans, IRC, Etc…
- **Freeze-Frame** and Fail Records
- **DTCs/Codes**
- **Work Support Data:** Coding, Module ID, Programming

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DiagNation

DME/PCM/ECM Typical Data Sets:
Fuel Control: Injection, Supply, Fuel Trims,
Emissions: O2/AFR Data
Ignition: Coils, Drivers, Feedback Data, Voltage Sense, Misfire
Exhaust: DPF/SCR, NOx O2/AFR, Catalytic Converter, Temp Sensors
Air Controls: MAF, MAP IAT, VGT, IAC, ETM, IRC, APP, TPS
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Freeze-Frame and Fail Records
DTCs/Codes
Work Support Data: Coding, Module ID, Programming

OEMs typically organize these data sets according to their engineer's preference. Some OEMs lump all of these into one data set, others break them down in similar fashion to the sets above.

Drivability PIDS and Analysis:

- Text and Numerical Data
- Binary or Hexadecimal Data
- Status On/Off Data
- Graphed PID Data
- Bar Chart Data
- Gage Style Data
- This is all determined by device engineers, platform, hardware and software configurations.
- Global OBDII Data
- Manufacturer Specific Data

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DiagNation

Text and Numerical Data
Binary or Hexadecimal Data
Status On/Off Data
Graphed PID Data
Bar Chart Data
Gage Style Data
This is all determined by device engineers, platform, hardware and software configurations. (Vehicle platform AND scanner platform)
Global OBDII Data
Manufacturer Specific Data

Things to Explore and Learn

- Study ***Magnetic Inductance*** and how it behaves in a circuit Study Impedance to understand the difference between Impedance and Ohmic Resistance in a circuit.
- ***All circuits and loads DO NOT directly follow Ohm's Law*** after inductance and impedance are introduced into the circuit. The physical math goes FAR beyond V=IxR in today's systems.
- Explore the RF world. It is becoming a large presence in our diagnostics. Get your tool sets and methodology dialed in, RF in automotive platforms is here to stay.
- Study the Time Constant vs Resistance and build an oscillator to run a motor. Then, drive a transistor with your oscillator, have some fun, hook up your scope and do some testing.
- Study AC currents, 3-Phase controls and motor testing. You'll need it.
- **Studying these fundamentals in theory and in practice is a never-ending learning curve for those who practice.**

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Build And Operate a Basic Oscillator Circuit
Build and operate PWM generator from R/C PWM circuit
Build 555 IC Chip Oscillator – you can drive TTL circuits to run loads on the bench (Coils, solenoids, etc) AND you can make your own functional signal generator.
Play with Inductors, Capacitors, Resistors
Explore XY Mode on your Lab Scope!

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DiagNation